Central Valley Project Improvement Act

Draft

Programmatic

Environmental

Impact

Statement

Technical Appendix

VOLUME TWO

US Department of the Interior

Bureau of Reclamation

Sacramento, California

LIST OF TECHNICAL APPENDICES
(SEPTEMBER 1997)

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CENTRAL VALLEY PROJECT IMPROVEMENT ACT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT TECHNICAL APPENDIX

Surface Water Supplies and Facilities Operations

September 1997

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LIST OF ABBREVIATIONS AND ACRONYMS

ACID	Anderson-Cottonwood Irrigation District
Act	Rivers and Harbors Act of 1935
CEQ	Council on Environmental Quality
cfs	cubic feet per second
COA	Coordinated Operations Agreement
COE	U.S. Army Corps of Engineers
CVGSM	Central Valley Groundwater and Surface Water Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
D_	State Water Resources Control Board Decision
DCC	Delta Cross Channel
Delta Plan	Delta Water Quality Control Plan
Delta	Sacramento - San Joaquin Delta
DFG	California Department of Fish and Game
DO	dissolved oxygen
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EID	El Dorado Irrigation District
GCID	Glenn-Calusa Irrigation District
M&I	municipal and industrial
mg/l	milligrams per liter
MID	Modesto Irrigation District
MOA	Memorandum of Agreement
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NWR	National Wildlife Refuge
OID	Oakdale Irrigation District
PCWA	Placer County Water Agency
PEIS	Programmatic Environmental Impact Statement
PG&E	Pacific Gas and Electric Company
PROSIM	Project Simulation Model
Reclamation	U.S. Bureau of Reclamation
RM	river mile
RWQCB	Regional Water Quality Control Board
SANJASM	San Joaquin Area Simulation Model
Service	U.S. Fish and Wildlife Service
SEWD	Stockton East Water District
SMUD	Sacramento Municipal Utility District
SSJID	South San Joaquin Irrigation District
SWP	State Water Project
SWRCB	California State Water Resources Control Board

TDS	total dissolved solids
TID	Turlock Irrigation District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
Western	Western Area Power Administration
WMA	Wildlife Management Area
WMP	Water Management Plan

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Draft Programmatic Environmental Impact Statement (PEIS) summarizes the evaluation of the direct and indirect impacts of implementing a wide range of actions identified in the Central Valley Project Improvement Act (CVPIA). Detailed information used in the definition of the affected environment and analysis of the environmental consequences are presented in more detail in the technical appendices of the Draft PEIS.

This technical appendix presents a summary of conditions that would affect surface water supplies and facilities operations, including background information that was used during the PEIS preparation, and the results of the impact analyses for conditions that occurred throughout the study area, shown in Figure I-1.

The surface water analysis was primarily based upon changes in CVP facilities operations, stream flows, water deliveries to CVP contractors, and the management of water acquired from willing sellers for delivery to wildlife refuges and for increased instream flows and Delta outflow.

The information from this technical appendix was used in all issue area analyses included in the Draft PEIS. Changes in river flows , reservoir operations, and water deliveries were used in the fisheries, groundwater, agricultural economics and land use, vegetation and wildlife, power, recreation and recreation economics, water transfer opportunities, municipal water costs, and cultural resources analyses.

The results of the analyses for Alternatives 1, 2, 3, and 4 and Supplemental Analyses 1a and 1d are presented in this technical appendix and summarized in the Draft PEIS. A summary of assumptions related to the surface water supplies and facilities operations analyses for these alternatives and supplemental analyses are presented in Table I-1. A summary of results of the surface water operations analyses of these alternatives and supplemental analyses are presented in Table I-2. The assumptions and results of Supplemental Analyses 1b, 1c, 1e through 1i, 2a through 2d, 3a, and 4a are summarized only in the Draft PEIS.

FIGURE I-1
STUDY AREA

TABLE I-1

SUMMARY OF ASSUMPTIONS FOR SURFACE WATER SUPPLIES AND FACILITIES OPERATIONS

No-Action Alternative	Projected 2020 level water demands based on water rights, CVP contract amounts, historical diversion data, and DWR Bulletin 160-93 projections. Continued CVP operations under CVP-Operations Criteria and Plan, October 1992. Continued operation of CVP and SWP under Bay-Delta Plan Accord, SWRCB D-1422, Winter Run Chinook Salmon and Delta Smelt Biological Opinions as amended in 1995, and Coordinated Operation Agreement. Shasta temperature control device in operation. SWP operations per Monterey Agreement.
1	No-Action Alternative assumptions plus the following: Implementation of 3406(b)(1)(B) and (b)(2) water management including Bay-Delta Plan Accord component and additional operations on Sacramento River, American River, Stanislaus River, and Clear Creek. Water accounting for (b)(2) water use based on changes in deliveries to CVP Water Service Contractors. Firm Level 2 refuge supplies per 1989 Refuge Water Supply Study. Includes a 25 percent shortage in Critical years per the Shasta Index. Increased Trinity River instream fishery flows.
1a	Alternative 1 assumptions plus the following: Implement preliminary (b)(2) water management actions in the Delta in addition to Bay-Delta Plan Accord.
1d	Alternative 1 assumptions plus the following: Delivery of full Level 2 refuge water supplies in all years without shortage.
2	Alternative 1 assumptions plus the following: Implement 3406(b)(3) water acquisition for Level 4 refuge water supplies. Acquire up to 170,000 af/yr from willing sellers on the Stanislaus, Tuolumne, and Merced Rivers for instream and Delta fishery needs.
3	Alternative 1 assumptions plus the following: Implement 3406(b)(3) water acquisition for Level 4 refuge water supplies. Acquire up to 800,000 af/yr from willing sellers on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba Rivers for instream fishery needs. Acquired water may be exported by the projects when it reaches the Delta.
4	Alternative 1 assumptions plus the following: Implement (b)(2) water management actions in the Delta in addition to Bay-Delta Plan Accord. Implement 3406(b)(3) water acquisition for Level 4 refuge water supplies. Acquire up to 800,000 af/yr on Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba Rivers for instream and Delta fishery needs. Acquired water may not be exported by the projects when it reaches the Delta.

TABLE I-2

SUMMARY OF IMPACT ASSESSMENT OF SURFACE WATER SUPPLIES AND FACILITIES OPERATIONS

Affected Factors	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Supplemental Analysis 1a	Supplemental Analysis 1d
Surface Water Deliveries		*Change from No-Action Alternative*				*Change from Alternative 1*	
Average Annual CVP Deliveries 1922 - 1990 (1,000 af/yr)	5,770	-470 (-8%)	-590 (-10%)	-390 (-7%)	-620 (-11%)	-100 (-2%)	-10 (0%)
Average Annual CVP Refuge Deliveries 1922 - 1990 (1,000 af/yr)	260	+230 (+88%)	+370 (+142%)	+370 (+142%)	+370 (+142%)	no change	+10 (2%)
Average Annual SWP Deliveries 1922 - 1990 (1,000 af/yr)	3,330	+100 (+3%)	+80 (+2%)	+270 (+8%)	-20 (-1%)[(1)]	-30 (-1%)[(1)]	no change

NOTE:
(1) Intent was to prevent impacts as compared to the No-Action Alternative. Minimal impacts are due to model limitations.

CHAPTER II

AFFECTED ENVIRONMENT

Chapter II

AFFECTED ENVIRONMENT

INTRODUCTION

This chapter provides an overview of historic and recent surface water conditions in Central Valley watersheds, and describes major federal, state, and local water supply projects within the Trinity River Basin and the Central Valley. Major surface water projects in these regions include the Central Valley Project (CVP), other federal water supply and flood control projects, the California State Water Project (SWP), and local surface water supply projects based in the Central Valley. Because the PEIS alternatives would primarily affect the operation of facilities and the delivery of surface water in the Central Valley, this chapter focuses primarily on rivers and water supply facilities in the Central Valley.

The Central Valley of California is a vast, oblong valley that runs down the interior of the state, 400 miles north-to-south and about 50 miles east-to-west. The Central Valley is flanked on the east by the Cascade and Sierra Nevada mountain ranges, and on the west by the Coast Range. Three major drainage areas are present in the Central Valley: the Sacramento River Basin, the San Joaquin River Basin, and the Tulare Lake Basin. The Sacramento River Basin consists of the northern third of the Central Valley and is drained by the Sacramento River, yielding approximately 35 percent of the total outflow of all rivers in the state. Most of the southern two-thirds of the Central Valley, a much drier region, is drained by the San Joaquin River, which flows west, then north, and meets the Sacramento River at the Sacramento-San Joaquin Delta (Delta). The Sacramento and San Joaquin rivers join in the Delta where their combined flows continue west through Susuin and San Francisco bays to the Pacific Ocean. The southernmost portion of the Central Valley, the Tulare Lake Basin, is an inland drainage area that receives flows from four rivers and several smaller streams that drain the western slope of the Sierra Nevada Range, and from several ephemeral streams that drain the eastern slope of the Coast Range. Figure II-1 shows major rivers and streams that drain Central Valley watersheds, and major water supply projects that affect streamflows.

This chapter begins with a historical perspective of water supply development in California, including significant events that affected the development of water resource facilities in the Central Valley. Following are descriptions of surface water conditions and facilities in the major watersheds in the Central Valley drainage areas in the Sacramento River, San Joaquin River, and Tulare Lake basins.

The watershed-based descriptions are followed by a summary of the CVP operational criteria, facilities in the various divisions and units of the CVP, site-specific and division-specific operational criteria, CVP contract types, and the process by which water delivery quantities are determined for each CVP contract type. Site-specific information is not provided

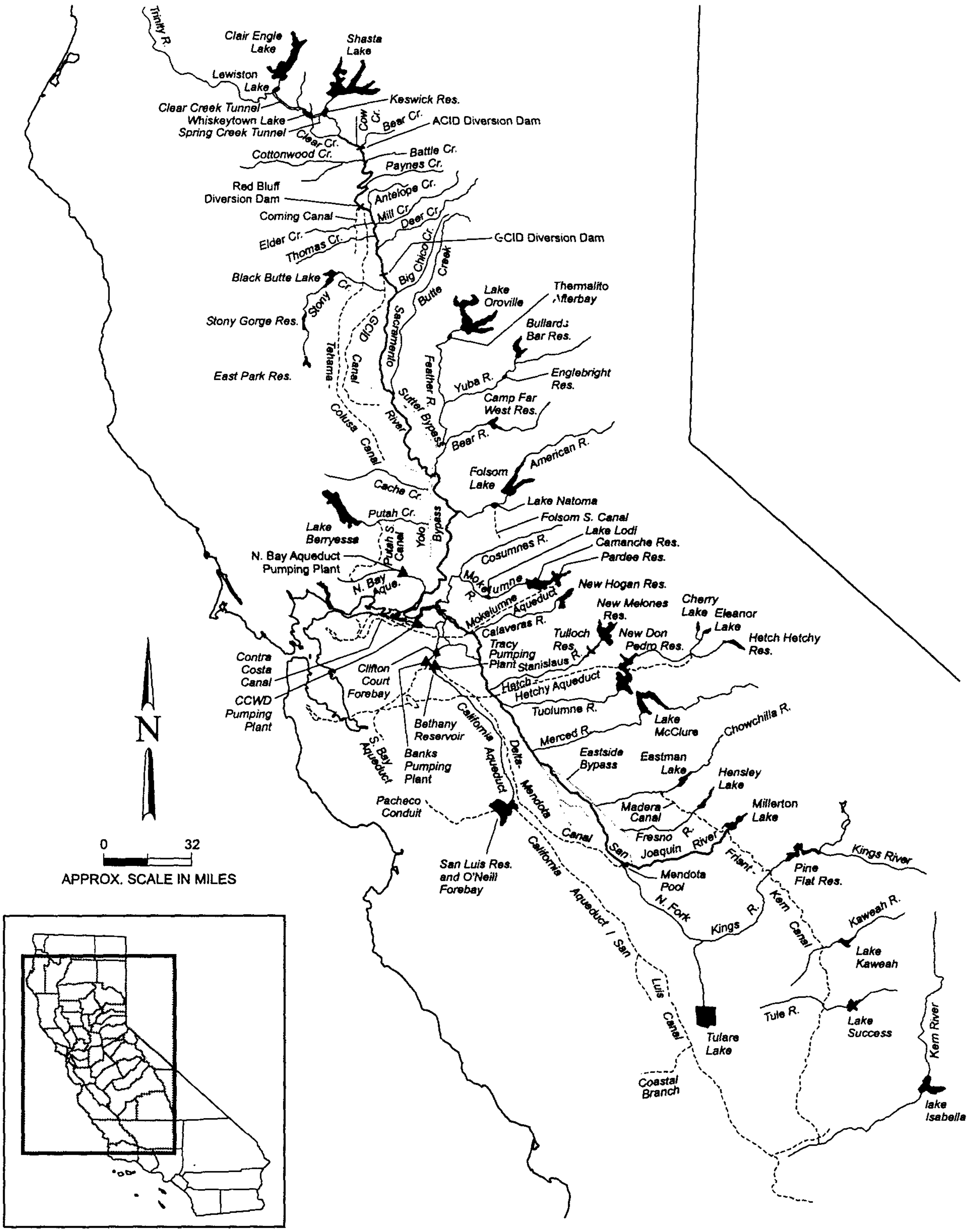

FIGURE II-1

SURFACE WATER FACILITIES

for all operational facets of individual facilities discussed in this chapter. Rather, information is presented on a division-wide or project-wide level, to illustrate the relationship of operations between facilities. As a result, the level of detail of information varies by facility. The description of the CVP is followed by a brief summary of the SWP facilities, operations, contractors, and decision-making criteria.

The general historical study period reviewed for water supply facilities extends from the inception of water supply development in California, in approximately 1770, to the present. Emphasis is placed on the period from 1940 to 1992 because the CVP, the SWP, and several local water supply projects were developed during this period.

IDENTIFICATION OF STREAMS IN THE STUDY AREA

Historic streamflow data were collected to provide a representation of streamflows in the study area. The level of detail of the PEIS precludes including data for all California streams therefore, only streams that may be affected by CVPIA actions are included. The selection of these streams was accomplished through a screening process, applying one or more of the following criteria:

- The stream includes a CVP facility or is directly affected by CVP operations.
- The stream was identified in the Central Valley Anadromous Fisheries and Riparian Habitat Protection and Restoration Action Plan prepared by the California Department of Fish and Game (DFG) (1993).
- The stream is used to convey CVP water to refuges.
- The stream has important water quality significance that affects CVP operations.

Table II-1 shows the results of the screening process.

DATA SOURCES

In the development of this document, data were collected to summarize historic streamflow conditions, surface water quality, the historical perspective, descriptions of facilities, and operations criteria. These data were obtained from a variety of sources, as described below.

Streamflow data were obtained from U.S. Geological Survey (USGS) published streamflow records. The USGS maintains daily stream flow data collected from more than 250 stream flow gauging stations throughout the Central Valley. The period of record varies from station to station. The selection of stations for use in this document was based upon several screening criteria. First, those gauges that provide a good representation of flow entering the valley floor from the surrounding mountains and gauges that represent flow in reaches of rivers on the valley floor were sought. Where multiple gauges are located on one reach of a river, the gauge located

TABLE II-1
SELECTION OF STREAMS FOR EVALUATION

Geographic Subregion	Stream Name	CVP Facilities or Directly Affected by CVP Operations	Central Valley Anadromous Fisheries	Conveys CVP Water to Refuges	Water Quality Concerns
Sacramento River Region					
	Sacramento River	X	X		
	Cow Creek		X		
	Bear Creek		X		
	Battle Creek		X		
	Paynes Creek		X		
	Antelope Creek		X		
	Mill Creek		X		
	Deer Creek		X		
	Big Chico Creek		X		
	Butte Creek		X		
	Feather River		X		
	Yuba River		X		
	Bear River		X		
	American River	X	X		
	Clear Creek	X	X		
	Cottonwood Creek		X		
	Elder Creek		X		
	Thomes Creek		X		
	Stony Creek (1)	X	X		
	Cache Creek				
	Putah Creek				
	Colusa Basin Drain			X	X
San Joaquin RiverBasin					
	San Joaquin River	X	X		X
	Cosumnes River	X	X		
	Mokelumne River	X	X		
	Calaveras River		X		
	Stanislaus River	X	X		
	Tuolumne River		X		

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TABLE II-1. CONTINUED

Geographic Subregion	Stream Name	CVP Facilities or Directly Affected by CVP Operations	Central Valley Anadromous Fisheries	Conveys CVP Water to Refuges	Water Quality Concerns
	Merced River		X		
	Chowchilla River (2)	X			
	Fresno River (2)	X			
	Fresno Slough			X	
	Mud Slough (3)			X	X
	Salt Slough (4)			X	
Sacramento-San Joaquin Delta					
	(no rivers listed)	X	X		
Tulare Lake Region					
	Kings River (5)	X			
	Kaweah River (5)	X			
	Tule River (5)	X			
	Deer Creek (5,6)			X	
	Poso Creek (5,6)			X	
	Kern River (5)	X			

NOTES:
(1) Stony Creek can be used to augment flows in the Tehama- Colusa Canal.
(2) At times used to convey Madera Canal deliveries and/or spills.
(3) At one time used to convey water to the southeast area of the Los Banos Wildlife Management Area (WMA).
(4) Used to convey water to the west side of the San Luis Wildlife Refuge.
(5) At times used to convey Friant-Kern Canal deliveries and/or spills.
(6) Not included in evaluation.

directly below the primary controlling structure was selected. Finally, gauging stations with longer periods of record were preferred, but when this was not possible, multiple gauges close to one another on the same stream were used. The selected USGS stream gauges are referenced on figures showing historic streamflow data in this chapter.

Surface water quality data were obtained from a variety of publications by the California State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Boards (RWQCB); the California Department of Water Resources (DWR); the USGS; and studies conducted by federal, state, and local agencies. Surface water quality data were not widely collected prior to the early 1950s. Since that time the USGS has been actively involved in the collection of water quality data for the surface waters of California. In addition, DWR, SWRCB, Reclamation, and various local agencies have conducted water quality monitoring programs. The U.S. Environmental Protection Agency (USEPA) has collected much of this information in a common database referred to as STORET.

The historical perspective on water development in California has been drawn from several works, including Cooper, 1968; Harding, 1960; U.S. Bureau of Reclamation (Reclamation), 1975 and 1981; Water and Power Resource Service, 1981; U.S. Army Corps of Engineers (COE), 1975; and the California Department of Water Resources (DWR), 1974. The first two of these publications provide a general historic overview of water development in California. The roles of Reclamation, the COE, and DWR in the development of water resource facilities are provided in the remaining documents.

Information regarding water supplies and water management facilities in the affected environment was collected from agencies responsible for the construction and operation of these facilities. Data employed in the preparation of this document were obtained in various forms, including published documents, unpublished data from agency files, and direct communication with agency personnel and others familiar with the water supplies and facilities in the Central Valley. Reclamation, the COE, DWR, and the USGS were particularly helpful in providing information presented in this chapter.

Descriptive information of several CVP facilities was drawn from the Water and Power Resources Service (1981). Descriptions of the operational criteria for CVP facilities were initially obtained from the *Long-Term Central Valley Project Operations Criteria and Plan* (Reclamation, 1992), and updated to reflect recent operational criteria. The description of the operational criteria for the SWP was obtained from the Delta Smelt Assessment (1993).

HISTORICAL PERSPECTIVE

Throughout the past 200 years, the development of water supplies for mining, agricultural, and municipal purposes in the Central Valley has been affected by numerous factors, including the influx of people to California during several significant events, periods of severe floods or drought, economic conditions, and legal considerations. A summary of events that have influenced the development and operation of water supply facilities in California during the past two centuries is provided on Table II-2.

TABLE II-2
EVENTS THAT INFLUENCED WATER SUPPLY DEVELOPMENT IN CALIFORNIA

Year	Event
1769	Spanish established permanent settlements in Alta, California.
1769	Spanish feral livestock introduced floral species to California.
1770	Zanja Madre constructed to convey water to the Pueblo de Los Angeles and adjacent irrigated areas.
1770s	First major storage, diversion, and conveyance irrigation project in California. Project was for San Diego Mission and included 12-foot-high dam and 245-foot-wide dam on San Diego River and 6 miles of canals.
1776-1815	Irrigation diversion systems constructed for San Juan Capistrano, San Fernando, San Luis Rey, Pala, and San Bernardino missions.
1805	Drought.
1809-1810	Drought.
1816-1817	Drought.
1820-1821	Drought.
1822	Mexico began land grant program.
1828-1830	Drought.
1830s	Many native plants consumed by feral livestock during droughts.
1830s	Significant decline in beaver.
1840-1841	Drought.
1841	Canal constructed from San Gabriel River to irrigation area near Azusa.
1846	Hudson Bay Company closed French Camp due to lack of beaver and antelopes.
1848	Gold discovered at Coloma.
1848	California annexed to United States.
1849	Gold Rush started.
1849	First major levee constructed in Delta on Grand Island.
1850	California became a state and adopted English Common Law, which included the concept of riparian rights.
1850	Congress adopted Arkansas Swamp Act to sell floodplain land to developers who would construct levees and drainage systems.
1850s	California legislature recognized Los Angeles and San Diego prior water rights on the Los Angeles and San Diego rivers, respectively.
1852	Wheaton Mining Dam constructed at La Grange on the Tuolumne River.
1852	Hydraulic mining started.
1853	Large irrigation facilities constructed to divert Mill Creek water (tributary of Kaweah River).
1854	Large irrigation facilities constructed near Snelling to divert Merced River water to alfalfa fields, orchards, and vineyards.
1857	Irrigation was provided to large areas of orchards and vineyards near Chico.
1859	Stockton constructed artesian wells to serve the city.
1859-1865	Large irrigation facilities constructed to divert Tule River water.
1860	California legislature authorized formation of levees and reclamation districts.
1860s	San Joaquin River flows high enough to allow shipping to Herndon.
1861-1862	Major floods changed many river channel configurations.
1863-1864	Drought.
1864	Feral livestock reduced due to droughts and rodeos.

TABLE II-2. CONTINUED

Year	Event
1867	Kern River: Water diverted through one canal to irrigate 700 acres.
1868	California legislature adopted Green Act that allowed formation of reclamation districts with taxing authority.
1869	Main and Outside canals constructed.
1860s-1870s	Primary crops in San Joaquin were wheat, barley, grass, and livestock (cattle and sheep).
1870	Drought.
1870	Drill rigs and engine-driven pump technology became available.
1870	Railroad constructed to Modesto.
1870	State Fish Commission created to enforce catch restrictions and require fish ladders for all physical obstructions.
1870s	People's, Last Chance, and Lemoore canals constructed to convey water from Kings River.
1870s	Railroad companies opened duck hunting clubs in Delta.
1871	Mendota Dam (Weir) constructed, and navigation impaired east of new dam.
1872	California legislature adopted the Statutes of 1872, which provide for appropriative water rights.
1872	Miller-Lux Canal constructed along west side of San Joaquin Valley to convey water from San Joaquin River.
1872	First salmon hatchery in California operated by U.S. Fish Commission. Hatchery located on the McCloud River in Shasta County.
1872-1873	Major economic depression.
1873	The Federal Alexander Commission completed study of Sacramento and San Joaquin rivers and encouraged development of water plan to transfer water from Sacramento River to San Joaquin River.
1873	Kern River: Water diverted through six canals to irrigate 7,000 acres.
1874	First release of fish from California hatchery (Eastern Brook Trout).
1874	Railroad constructed to Bakersfield.
1874	California legislature adopted the 1874 Act, the first law to address groundwater and conservation.
1874	Federal Law, No Fence Law, required livestock owners to pay for damages of wandering livestock. This law favored farmers over ranchers and reduced feral livestock that ate native vegetation.
1877	Desert Land Act of 1877 allowed Haggin and other landholders to acquire odd-numbered land sections that had been covered under the Railroad Land Grant.
1878	State Engineer, Hall, studied irrigation, drainage, and navigation problems on Sacramento and San Joaquin rivers.
1878	Kern Lake eliminated due to drought and diversions.
1879	Striped bass introduced to Delta.
1880	Kern River: Water diverted to irrigate 40,000 acres.
1880	Farmer's Canal constructed to convey Merced River water.
1880	Kings River: Water diverted to irrigate 85,000 acres.
1880	State Fish Commission became responsible for game as well as fish.
1880	California legislature approved Drainage Act to provide flood control in Central Valley.
1880s	University of California, Berkeley, reported that the Kern River had excessive salts, and that Tulare Lake water quality was extremely poor due to return flows and could not be used for irrigation or potable water supplies.

TABLE II-2. CONTINUED

Year	Event
1880s	Artesian wells constructed throughout San Joaquin Valley (including a 7-foot diameter well, 330-feet-deep, with 800,000 gallons-per-day production capacity).
1880s	Many woodlands disappeared for fences and fuel, including fuel for pumps.
1880s	Large salmon canneries on Sacramento River (2.9 million pounds per year).
1884	Federal injunction banned use of hydraulic mining unless sediment was controlled (Woodruff vs North Bloomfield et al.)
1887	Wright Act adopted that allowed for formation of public irrigation districts.
1890s	Central Irrigation District started construction of large facilities near Glenn-Colusa area.
1890s	Electric and natural gas pumps installed in San Joaquin Valley.
1890s	Extensive hunting of white swans, mink, gray fox, weasel, kit fox, bison, and bighorn antelope caused major reduction of populations. Hunters also reduced populations of bears, rabbits, deer, quails, and pigeons. American Common Egret hunted for feathers. Turkey vultures and California Condor hunted for target practice.
1892	Congress established California Debris Commission to remove mining debris from rivers and navigable waters.
1892	Railroad constructed to Fresno.
1893	Modesto Irrigation District (MID) and Turlock Irrigation District (TID) constructed La Grange Dam on Tuolumne River. TID began diversions in 1900 and MID began diversions in 1903.
1895	Debris dams constructed along Sacramento River tributaries.
1895	(Old) Folsom Dam constructed on the American River.
1897	California Legislature adopted Bridgeford Act to define irrigation districts rights that would increase profitability of districts.
1900s	Demand for wheat declined as England found other sources. Railroads increased demand for rice, orchard and row crops, dairies, and cotton.
1900	Bear River Dam on Mokelumne River completed.
1901	State Fish Commission adopted bag limits for waterfowl (50 birds per day).
1902	Union Dam completed on North Fork Stanislaus River.
1902	Congress adopted Reclamation Act.
1904	Sutter Butte Canal Company started construction of large facilities near Gridley.
1905	Shaver Dam completed on Stevinson Creek
1905	Pacific Gas and Electric Company (PG&E) incorporated.
1906	San Joaquin Valley: 522 artesian wells and 597 electric or gas pumps on wells.
1906	Alpine Dam completed on Silver Creek.
1907	First striped bass hatchery was operated by State Fish Commission on Bouldin Island.
1908	First wells constructed in Kern County to serve citrus orchards.
1910	San Joaquin Valley: 5,000 electric or gas pumps on wells.
1910	The U.S. Reclamation Service completed studies of the Kings, Pit, and San Joaquin rivers, developed the Orland Project, and studied the Iron Mountain Dam.
1910	Utica Dam completed on North Fork Stanislaus River.
1911	Use of airplanes to hunt waterfowl began.
1912	Goodwin Dam completed on Stanislaus River.
1913	MID constructed Dallas-Warner Reservoir on Tuolumne River.
1913	Congress passed Raker Act, which allowed San Francisco to divert water from Tuolumne River. The Act also required San Francisco to protect prior water rights of MID and TID, to provide roads into Yosemite park, and to restrict sales of power produced from project.

TABLE II-2. CONTINUED

Year	Event
1913	Almanor Dam completed on North Fork Feather River.
1913	General angling license required in California for all persons over 18 (cost was $1 per person).
1914	Sacramento River Flood Control Project levees constructed to minimize flooding due to increased elevation of river bed caused by mining debris.
1914	Water Commission Act enacted to establish system to deliver appropriative water rights.
1914-1918	World War I.
1916	Newer Mendota Dam constructed with movable section to allow navigation.
1915	Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID) began diversions from Stanislaus River.
1915	To protect public health, Sacramento began to chlorinate water supply.
1915	State Water Problems Conference discussed many problems, including riparian rights.
1916	First shad hatchery was operated on Feather River near Yuba City.
1916	Main Strawberry Dam completed on South Fork Stanislaus River.
1919	Merced Irrigation District constructed Exchequer Dam and Power Plant.
1919	USGS developed the Marshall Plan that recommended a series of storage reservoirs on the Sacramento River with large canals along the west and east sides of the Sacramento and San Joaquin valleys, and diversion of the Kern River to Los Angeles.
1920	San Joaquin Valley: 11,000 electric or gas pumps on wells.
1920	Irrigation along Suisun Marsh abandoned due to high salinity caused by drought.
1920-1930	Drains installed in over 5,000 farms in the San Joaquin Valley.
1923	O'Shaugnessy Dam (Hetch Hetchy Reservoir) constructed on Tuolumne River.
1923	MID and TID constructed Don Pedro Reservoir on Tuolumne River.
1924	To protect public health, Sacramento began to filter water supply.
1924	Melones Dam constructed on the Stanislaus River.
1924	Nevada Irrigation District allowed PG&E to build powerplants on existing reservoirs on Yuba and Bear rivers.
1924	(Old) Bullards Bar Dam completed on Yuba River.
1925	Lake Briton Dam completed on Pit River.
1925	Pit River No. 3 Dam completed.
1925	Calaveras Dam completed.
1927	Pit River No. 4 Dam completed.
1927	Herminghaus v. Southern California Edison Company decided that a senior riparian right to flood flows (overflow) was superior to an appropriative ight for a storage project. This case precipitated the constitutional amendment regarding reasonable and beneficial use.
1927	Bucks Dam completed on Bucks Creek.
1927	Balch Diversion Dam completed on North Fork Kings River.
1928	California legislature adopted a constitutional amendment that while preserving riparian rights prohibited waste of water and established the reasonableness doctrine.
1928-1934	Drought.
1929	Lower Bucks Lake Dam completed on Bucks Creek.
1929	Pardee Dam and Mokelumne Aqueduct completed, diversions of Mokelumne River water to East Bay Municipal Utility District EBMUD) began.
1930	Lyons Dam on South Fork Stanislaus River completed.

TABLE II-2. CONTINUED

Year	Event
1930	San Joaquin Valley: 23,500 electric or gas pumps on wells.
1930s	Fertilizers and vector poisons were introduced on farmlands.
1931	The Federal Government and the State Water Resources Commission (Hoover-Young Commission) recommended that the Federal government construct the Central Valley Project and the State operate the facilities. The State Water Resources Commission said that the project would be economical if the interest rate was not more than 3.5 percent
1931	Salt Springs Dam completed on North Fork Mokelumne River.
1933	State of California authorized bonds for $170 million for the CVP Shasta Dam and Power plant, Friant Dam and Power plant, Contra Costa Canal, Madera Canal, Friant Kern Canal, other dams and pumps on the San Joaquin River, transmission lines from Shasta to Antioch, and a pump between the Sacramento and San Joaquin rivers. Due to the economic conditions of the Great Depression, bonds not purchased.
1934	Hetch Hetchy Aqueduct completed; diversion of Tuolumne River water to San Francisco began.
1935	Federal government approved $20 million in Emergency Relief Appropriation Fund and the CVP authorized by the Rivers and Harbors Act.
1937	Congress reauthorized Rivers and Harbors Act including reauthorization of the CVP and stated the purposes of the project.
1939	Construction of Friant Dam on the San Joaquin River began.
1939-1945	World War II.
1940	Congress reauthorized Rivers and Harbors Act including reauthorization of the CVP by restating the purposes of the project and including authorization for construction of local distribution systems as part of CVP construction projects.
1940	Water diversions start at Contra Costa Canal.
1941	U.S. enters World War II.
1943	Pit River Dam No. 5 completed.
1944	Diversions to upper portion of Madera Canal from Friant Dam on the San Joaquin River began
1944	Congress adopted Flood Control Act of 1944 including authorization for Shasta, Folsom, and New Melones dams
1944	Shasta Dam completed on the Sacramento River, initial CVP water contracts signed, and water diversions began.
1945	Madera Canal completed.
1947	Diversions from Friant Dam on the San Joaquin River to the upper portion of the Frian-Kern Canal began.
1948	COE began planning Iron Mountain Dam on Sacramento River and Pine Flat Dam on Kings River.
1948	Contra Costa Canal completed.
1949	Friant Kern Canal completed.
1950	CVP signs water rights contracts with riparian and senior appropriate water rights holders on Sacramento and American rivers.
1950	Keswick Dam completed on the Sacramento River downstream of Shasta Dam.
1951	Delta Cross Channel (DCC), Delta-Mendota Canal, and Tracy Pumping Plant completed, allowing for delivery of Delta water to San Joaquin River Exchange Contractors. Releases from Friant Dam reduced.
1951	Pine Flat Dam completed on Kings River.
1954	Isabella Dam completed on Kern River.

TABLE II-2. CONTINUED

Year	Event
1954	Congress adopted Grassland Development Act to add fish and wildlife purposes as authorized purposes for CVP and to authorization for cooperation with the state to supply water to Grasslands for waterfowl cooperation.
1955	Nimbus Dam and Powerplant on the American River completed.
1955	Sly Park Dam and Sly Park-Camino Conduit completed on Sly Park Creek.
1955	Congress adopted Trinity River Act to authorize Trinity River Division to allow for preservation and propagation of fish and wildlife.
1956	Congress reauthorized Reclamation Project Act including provision for right of renewal for long-term CVP agricultural user contracts for terms not to exceed 40 years.
1956	Folsom Dam completed on the American River.
1956	Cherry Valley Dam completed on Cherry Creek.
1957	State Water Plan completed.
1957	Beardsley Dam on Middle Fork Stanislaus River.
1957	Donnel Dam on Middle Fork Stanislaus River.
1957	Wishon Dam completed on North Fork Kings River.
1958	Tulloch Dam on Stanislaus River.
1958	Courtright Dam completed on Helms Creek.
1958	Congress adopted Fish and Wildlife Coordination Act to integrate Fish and Wildlife Conservation programs with federal water resources facilities, to authorize facilities to mitigate CVP-induced damages to fish and wildlife resources, and to require consultation for CVP facilities with Fish and Wildlife Service (Service).
1959	State legislature adopted State Water Plan.
1959	Putah South Canal diversions began.
1959	Mammoth Pool Dam completed on San Joaquin River.
1959	COE adopted flood control regulations for Folsom operations.
1960	Congress adopted San Luis Authorization Act to authorize the San Luis Unit and provide for Reclamation participation in recreation facilities.
1960	Sacramento Ship Channel under construction (Authorized in 1946).
1960	Burns-Porter Act approved to finance SWP.
1961	DWR establishes Interagency Delta Committee to evaluate solutions to Delta problems.
1961	Little Grass Valley Dam completed on South Fork Feather River.
1961	Success Dam completed on Tule River.
1962	Terminus Dam completed on Kaweah River.
1962	South Bay Aqueduct completed.
1962	Union Valley Dam completed on Silver Creek.
1963	Congress reauthorized the Reclamation Project Act including provisions for right of renewal for long-term municipal and industrial (M&I) contracts.
1963	Black Butte Dam completed on Stony Creek.
1963	Whiskeytown Dam completed on Clear Creek.
1963	Camp Far West Dam completed on Bear River.
1963	Loon Lake Dam completed on Gerle Creek.
1963	New Hogan Dam completed on Calaveras River.
1963	Camanche Dam completed on Mokelumne River.
1963	Lewiston Dam, Carr PowerPlant, and Clear Creek Tunnel completed.

TABLE II-2. CONTINUED

Year	Event
1964	Trinity Dam completed on the Trinity River.
1964	Corning Canal and Pumping Plant completed.
1964	Red Bluff Diversion Dam completed on the Sacramento River.
1965	Congress adopted Auburn-Folsom South Unit Authorization Act to authorize the Auburn-Folsom South Unit including participation in development of recreation facilities.
1965	Anderson Dam completed on Middle Fork American River.
1965	Los Banos Dam completed on Los Banos Creek.
1966	Grizzley Valley Dam completed on Big Grizzley Creek.
1966	Little Panoche Detention Dam completed on Little Panoche Creek.
1966	O'Neill Dam completed.
1967	San Luis Canal and Dam completed.
1967	New Exchequer Dam completed on Merced River.
1967	Whiskeytown Conduit completed.
1967	SWRCB adopted Water Quality Control Plan for Sacramento-San Joaquin Delta pursuant to Federal Water Pollution Control Act of 1965.
1967	SWP Delta Pumps and California Aqueduct completed.
1967	Bella Vista Conduit and Pumping Plant completed on Sacramento River.
1967	Oroville Dam completed on the Feather River.
1967	Pit River Dams 6 and 7 completed.
1967	Reclamation and PG&E signed agreements to allow excess CVP power and capacity to be sold to PG&E, and for PG&E to deliver power to CVP customers.
1969	Congress adopted the National Environmental Policy Act (NEPA).
1969	New Bullards Bar Dam completed on the Yuba River.
1970	New Don Pedro Dam completed on the Tuolumne River.
1970	Council on Environmental Quality published CEQ regulations for compliance with NEPA.
1971	SWRCB adopted Water Rights Decision (D-)1379 establishing Delta water quality standards.
1971	Tehama Colusa Canal and Pumping Plant completed.
1973	Congress adopted Endangered Species Act.
1973	First phase of Folsom South Canal completed.
1974	Congress adopted Clean Water Act.
1975	Cross Valley Canal completed.
1975	Buchanan Dam completed on Chowchilla River.
1976	Funks Dam completed on Funks Creek.
1976-1977	Drought.
1977	COE adopted flood control regulations and flood control diagram to describe flood potential and ratings for Shasta Dam operations.
1978	SWRCB adopted D-1485 to guarantee water quality protections for agricultural, municipal M&I, and fish and wildlife uses.
1978	New Melones Dam completed on the Stanislaus River.
1979	Hidden Dam completed on Fresno River.
1980	COE adopted flood control regulations for New Melones Dam operations.
1981	Sugar Pine Conduit and Dam completed on Shirttail Canyon.

TABLE II-2. CONTINUED

Year	Event
1981	Secretary of the Interior allocated CVP yield for minimum Trinity River flows of 340,000 acre-feet per year in normal water years, 220,000 acre-feet per year in dry years, and 140,000 acre-feet per year in critically dry years.
1982	COE adopted flood control diagrams with flood potential and ratings for New Melones Dam operations.
1982	Congress adopted Reclamation Reform Act.
1986	COE adopted flood control diagrams with flood potential and ratings for Folsom Dam operations.
1986	Congress adopted Public Law 99-546 to ensure repayment of plant-in-service costs of the CVP by 2030, and to include total costs of water supply, distribution, and service costs in the capital and operation costs in the CVP contracts.
1986	Coordinated Operations Agreement (COA) adopted by Congress and the California legislature to identify the water supplies of the CVP and SWP, allow for a negotiated sharing of Delta excess outflows, meet in-basin obligations between the CVP and SWP.
1986	Extreme rainfall.
1987	San Felipe Unit facilities completed.
1987	North Bay Aqueduct completed.
1987-1992	Drought.
1989	Sacramento River winter-run chinook salmon listed as endangered species by the State of California and as threatened by the federal government.
1990	SWRCB adopted Water Rights Order 90-05 to modify CVP water rights by incorporating temperature control objectives in upper Sacramento River.
1991	SWRCB adopted Water Rights Order 91-01 to modify Water Rights Order 90-05 to incorporate updated data and schedules.
1991	Secretary of the Interior amended previous decision to increase Trinity River minimum flows to 340,000 acre-feet per year for all years except critically dry, and for 340,000 acre-feet per year for critically dry years if at all possible.
1992	National Marine Fisheries Service (NMSF) issued interim Biological Opinion to protect winter-run chinook salmon.
1992	SWRCB issued draft Decision 1630 with updated Bay-Delta water quality standards.
1992	CVPIA enacted.
1993	NMFS issued final Biological Opinion to protect winter-run chinook salmon.
1993	Service issued interim Biological Opinion to protect Delta smelt.
1993	SWRCB withdrew draft Decision 1630 to concentrate on long-term solution for the Bay-Delta water quality problems.
1993	Service issued updated draft interim Biological Opinion to protect Delta smelt with provisions for Sacramento splittail.
1993	U.S. Environmental Protection Agency (USEPA) issued draft Bay-Delta water quality standards in response to court orders following withdrawal of Decision 1630 by the SWRCB.
1994	The Bay-Delta Plan Accord established a set of water quality goals for the Delta and tributary watersheds, including an interim agreement that provided for the CVP and SWP to meet the water quality goals until a final solution was developed that could involve participation by other upstream water users.
1995	The CALFED program was established to develop a solution provided for under the Bay-Delta Plan Accord. SWRCB D-95-06 included provisions to meet the requirements of the biological opinions for winter-run chinook salmon and delta smelt. Based upon these requirements, the Service and NMFS found that the operations under D-95-06 would not cause additional jeopardy to the winter-run chinook salmon and delta smelt.

1700s TO 1850

Water supply development, which has had a profound effect on the history of California, began well before the state was admitted into the Union. In 1772, construction of the first water storage and diversion project was begun, consisting of a dam on the San Diego River and 6 miles of canals to provide irrigation water to fields surrounding the San Diego Mission. As other missions were established, similar water supply and irrigation projects were also developed. By 1815, irrigation diversion systems had also been constructed for San Juan Capistrano, San Fernando, San Luis Rey, Pala, and San Bernardino missions. These projects were relatively small by today's standards, but firmly established the practices of diversion, storage, and conveyance of water for irrigation purposes.

The discovery of gold at Sutter's Mill on the American River at Coloma in 1848 prompted an influx of settlers to the Central Valley. This event, as well as several subsequent developments, began a trend of westward expansion that continued and grew through several decades.

By the signing of the Treaty of Guadalupe Hidalgo in 1848, what is now California was ceded from Mexico to the United States. All property rights under Mexican law, including private riparian water rights and public water rights attached to the pueblos, were preserved with the cession. As a result, the cities of Los Angeles and San Diego possess pueblo rights.

1850 TO 1920

After California was granted statehood in 1850, the first state legislature adopted the common law of England which, much like the Spanish/Mexican system, included the doctrine of riparian rights. At the same time, the miners had developed a system of "posting notice" at their points of diversion to substantiate their rights to take and transport water. This custom marked the birth of right by priority of appropriation, often referred to as "first in time, first in right," from which grew California's system of appropriative water rights. Appropriative water rights were given statutory recognition in 1872, 22 years after California was granted statehood. Also in the 1850s, the first legislature recognized the importance of water in the state's development and established the Office of Surveyor General to study the problems of navigation, drainage, and irrigation. As more settlers moved to California during ensuing years, the number of farms and extent of irrigated lands in the Central Valley continued to increase, as many of the miners abandoned their diggings and began irrigation farming to provide food for the increasing population.

The early irrigators were mostly individuals who relied on small water supply facilities that provided little long-term storage or flood control, and as a result crops were often ruined by devastating droughts and floods. In the San Joaquin Valley during the period from 1850 to 1870, water was diverted and conveyed through crude ditches for the irrigation of pasture lands and to provide feed in the dry summer and fall periods. During this period, demands for agricultural irrigation increased as the mining boom provided a nearby market for agricultural products. This demand was further stimulated by completion of the transcontinental railroad, which enabled exports of fruits and vegetables from California to markets elsewhere in the nation. By the 1870s, construction of larger irrigation works was well under way in the San Joaquin and Sacramento valleys, particularly in the vicinity of the Kings River. Substantial wooden and stone diversions were built in the rivers, and miles of canals were scraped out by farmers. Flows in most of the San Joaquin Valley rivers dwindled rapidly after June or July, however, often leaving crops with insufficient moisture to mature.

In the Delta, irrigation supplies for reclaimed lands were obtained through diversions from adjoining channels. In dry years, summer inflows to the Delta from the Sacramento and San Joaquin rivers were not sufficient to supply the large quantities of water consumed through irrigation, evaporation, and the growth of riparian vegetation and still maintain a positive outflow through the Delta. As a result, ocean water often encroached into the Delta, forcing irrigation to cease because of crop damage.

As early as the last quarter of the 19th century, the need for coordinated water development began to emerge as a critical element to sustain existing and growing water demands in the Central Valley. Following a severe drought of 1870, Congress in 1873 authorized the Alexander Commission to study the water supply of the Sacramento and San Joaquin rivers, and to develop solutions for water management. In his report, Alexander outlined a system of large-scale irrigation-water supply works, and suggested that federal assistance would be required to accomplish these recommendations.

The development of the gasoline engine in the 1890s, and the availability of electricity by the early 1900s, permitted economical pumping of groundwater from considerable depths. This capability was exploited extensively in the eastern San Joaquin Valley to provide either primary or supplemental water supplies for irrigated lands. The use of groundwater for domestic, municipal and agricultural uses resulted in the depletion of groundwater reserves in excess of annual recharge from streams and precipitation, and marked the beginning of groundwater overdraft conditions in the Central Valley. By the early part of the 20th century, after a series of very dry years, the groundwater in the San Joaquin Valley had become seriously depleted and many farmers and ranchers had left the land. It had become apparent that individual and local planning efforts would no longer be sufficient to resolve the water supply and management problems that affected local areas, the Central Valley, and California as a whole.

Federal assistance to western irrigation planning was authorized by Congress with the adoption of the Reclamation Act of 1902, creating the Reclamation Service, which later became the U.S. Bureau of Reclamation. Federal involvement in the development of California water facilities focused on two fundamental goals: water conservation and flood control. Reclamation was assigned responsibility for the development of water supply projects that would include mechanisms for repayment in accordance with reclamation law. The responsibility for navigation and flood control along major rivers in the Central Valley was assigned to the COE. In recognition of the protective nature of flood control and navigation, these types of projects did not include repayment provisions. Because of the opportunity to accomplish water supply, flood control, and navigation benefits with individual projects, the federal government coordinated the development of flood control and reclamation projects to the greatest extent possible, and federal reservoirs were designed to serve multiple purposes. During the next 30 years, the federal government (Reclamation and COE) and the State of California cooperated in surveys of the Central Valley to coordinate water supply planning activities.

1920 TO 1940

In 1920, Col. Robert Marshall, chief geographer for the USGS, proposed a major water storage and conveyance plan to transfer water from northern California to meet urban and agricultural needs of central and southern California. Under the Marshall Plan, a dam would be constructed on the San Joaquin River near Friant and water would be diverted to areas north and south in the eastern portion of the San Joaquin Valley. The diverted water would provide a supplemental supply to relieve some of the dependency on groundwater that had led to overdraft conditions in areas of the eastern San Joaquin Valley. In addition, surplus water in the Sacramento Valley would be collected, stored, and transferred to the San Joaquin Valley by a series of reservoirs, pumps, and canals. The main storage facility would be Shasta Dam, on the Sacramento River at its confluence with the McCloud and Pit rivers. Hydroelectric power generated at Shasta Dam would provide the power to lift project water from the Delta to irrigated lands in the San Joaquin Valley. A portion of this water would be delivered to San Joaquin River water rights holders, in exchange for water diverted at Friant Dam.

Initial Authorization of the Central Valley Project

During the 1920s, the California state legislature commissioned a series of investigations to further evaluate the Marshall Plan, and in 1933, approved the Central Valley Project Act. This Act authorizated for the construction of initial features of the CVP, including Shasta Dam and powerplants on the Sacramento River; Friant Dam on the San Joaquin River; power transmission facilities from the Shasta dam site to Tracy; and the Contra Costa, Madera, and Friant-Kern canals. The Act authorized the sale of revenue bonds to construct the project, but during the Great Depression the bonds could not be sold. The state therefore appealed to the federal government for assistance in the construction of the CVP. With the passage of the Rivers and Harbors Act of 1935, Congress appropriated funds and authorized construction of the CVP by the COE. When the act was reauthorized in 1937, the construction and operation of the CVP was assigned to Reclamation, and the CVP became subject to reclamation law. Construction of the CVP began on October 19, 1937, with the Contra Costa Canal. Construction of Shasta Dam was begun in 1938.

Other Water Supply Projects

Also during the 1920s, several large reservoirs were constructed in Northern California, mainly for municipal water supplies or the generation of hydroelectric power. The most significant of these projects include water supply projects for the City of San Francisco and the East Bay Municipal Utility District (EBMUD). The City of San Francisco's Hetch Hetchy Project, completed in 1923, brought water from the Tuolumne River to residents of San Francisco and San Mateo counties. Pardee Reservoir on the Mokelumne River and the Mokelumne Aqueduct began serving water to East Bay communities in 1929. In addition to these municipal water supply developments, other local water supply and hydroelectric generation projects were constructed on rivers tributary to the Sacramento and San Joaquin rivers. Neither the development nor the operation of these projects, however, had been coordinated on the basis of integrated water resource management for the basin.

1940 TO 1970

The period between 1940 and 1970 witnessed the most extensive development of water projects in California. This period of rapid expansion of water supply and flood control projects coincided with explosive growth in population and development of infrastruture in the years following World War II. During this period, most of the current features of the CVP and SWP were constructed, several other federal dams and reservoirs were constructed, and several locally owned and operated dams and reservoirs were constructed or expanded.

Expansion of the Central Valley Project

In the early 1940s, during World War II, construction of the initial features of the CVP continued, with the completion of Shasta Dam in 1944, followed by the completion of Friant Dam, and the Madera, Friant-Kern and Contra Costa canals between 1945 and 1949. Completion of the Delta Cross Channel, Tracy Pumping Plant, and Delta-Mendota Canal in 1951 enabled initial operation of Delta export facilities and delivery of water to the San Joaquin River Exchange Contractors.

By the late 1940s, it had become apparent that California's rapid urban, agricultural, and industrial growth would quickly increase demands for water and power to levels that exceeded the initial CVP system capacity. In response to this increase in projected demand, the COE and Reclamation evaluated an enlargement of Folsom Dam and Reservoir (originally authorized for construction by the COE as a flood control facility in 1944) to also provide water supply and hydroelectric power and be integrated into the CVP. In 1949, Congress passed the American River Act, which authorized the American River Division of the CVP and provided for the construction of Folsom and Nimbus dams, lakes, and powerplants. This action converted the single-purpose authorization of a flood control reservoir into a substantially enlarged multiple-purpose project integrated into the CVP. The act authorized the financial integration of the American River Division into the CVP, enabling coordination of water releases between Shasta and Folsom for flood protection and water supply, and the optimization of power accomplishments.

Through the 1950s and 1960s, the CVP service area and water storage capability continued to expand with the authorization and construction of additional divisions and units. In 1950, legislation was enacted to reauthorize the entire CVP to include the Sacramento River Division, which includes facilities to divert and deliver water from the Sacramento River to lands in the western Sacramento Valley. In 1955, the Trinity River Division was authorized for construction and integration to the CVP. Facilities were authorized to collect and store water in the Trinity River Basin, to transfer stored water to the Sacramento River Basin to increase supply available for irrigation in the Central Valley, and to generate hydroelectric energy.

The Flood Control Act of December 22, 1944, provided the original authorization for construction of New Melones Dam and Reservoir on the Stanislaus River by the COE to help alleviate serious flooding problems along the Stanislaus and lower San Joaquin rivers. In 1962, Congress expanded and reauthorized the project (PL 87-874) for operation by the Secretary of the Interior as an integral part of the CVP. Construction of New Melones was completed in

1979, and the facility was turned over to Reclamation in 1980 for operation as part of the Eastside Division of the CVP.

The San Luis Unit, in the western San Joaquin Valley, was authorized by Congress in 1960 as either a separate federal project or a joint federal-state undertaking. Following additional study, a contract between the federal government and the State of California was executed in 1961 for the joint construction and use of certain San Luis Unit features, including facilities for off-stream storage and conveyance. In 1965, the Auburn-Folsom South Unit was authorized to increase the water supply available for irrigation and other beneficial uses in the Central Valley.

In 1967, the San Felipe Division was authorized as an integral part of the CVP to provide water supplies to portions of the Santa Clara and Pajaro valleys. These valleys lie outside and west of the Central Valley Basin, and are served by a pipeline from San Luis Reservoir. The San Felipe Division is the only part of the CVP that provides service to areas outside the Central Valley Basin.

California State Water Project

In addition to the expansion of the CVP, planning for the multipurpose SWP began shortly after World War II. In 1947, the state began an investigation of its water resources and needs and prepared The California Water Plan, which outlined preliminary plans to meet the state's anticipated water needs through development of the SWP. In 1960, California voters authorized construction of the SWP by ratifying the Burns-Porter Act. At that time, the plans recognized that there would be a gradual increase in water demand and that construction of some facilities would be deferred until a later time. Initial projects included Oroville Dam and Lake Oroville on the Feather River, San Luis Dam and Reservoir, which were constructed and are jointly operated with Reclamation, the North and South Bay aqueducts, and the California Aqueduct. Deliveries from the SWP began in 1962, just two years after the start of construction.

Other Water Supply Projects

Since 1940, several major water supply projects have been constructed on Central Valley rivers. On rivers tributary to the Delta, dams and reservoirs were constructed by the COE local agencies on the Merced, Tuolumne, Calaveras, American, and Yuba rivers that affected flow conditions in these rivers, and modified inflow to the Delta. In addition, major dams and reservoirs were constructed in the Tulare Basin along the Kings, Kaweah, Tule, and Kern rivers. These facilities have reduced the incidence of flooding in the Tulare Lake Basin and have provided a more reliable local water supply to an area of extensive agricultural production.

1970 TO PRESENT

After 1970, the rate of water supply development in the Central Valley declined significantly. Most construction during this period was related to the completion of previously authorized projects. The only CVP facility constructed during this period was New Melones Dam and Reservoir on the Stanislaus River.

During the 1970s, the COE developed Hidden and Buchanan dams on the Fresno and Chowchilla rivers, respectively, to provide flood protection to downstream areas. These projects have been integrated into the CVP, and provide a portion of the water supply to CVP contractors along the Madera Canal on the east side of the San Joaquin Valley.

Currently, a total of 181 federal reservoirs in California provide a combined storage capacity of nearly 22 million acre-feet. In addition, more than 1,200 non-federal dams are under supervision by the State of California. This generally includes dams 25 feet or higher, or those that create a reservoir larger than 50,000 acre-feet. The reservoirs formed by these dams provide a cumulative storage capacity of approximately 20 million acre-feet The total combined capacity of federal and non-federal reservoirs, approximately 42 million acre-feet, represents over half of the estimated 71 million acre-feet of annual runoff throughout the state (Reclamation, 1975). A summary of major reservoirs discussed in this document, including storage capacity, watershed, owner, and year completed, is provided in Table II-3.

SURFACE WATER IN THE SACRAMENTO RIVER BASIN

The Sacramento River Basin, shown in Figure II-2, encompasses an area over 24,000 square miles in the northern portion of the Central Valley. It includes the McCloud River, Pit River, and Goose Lake basins to the north, extends from the foothills of the Coast Ranges and Klamath Mountains on the west, to the foothills of the Sierra Nevada and Cascade Range on the east. To the south, the basin is bordered by the Delta. Drainage is provided by the Sacramento River, which flows generally north to south from its source near Mount Shasta to the Delta, and receives contributing flows from numerous major and minor streams and rivers that drain the east and west sides of the basin.

Ground surface elevations in the northern portion of the Sacramento River Basin range from about 6,500 feet in the headwaters of the Sacramento River to approximately 1,065 feet at Shasta Lake. In this area, total annual precipitation averages between 60 and 70 inches, and is as high as 95 inches in the Sierra Nevada and Cascade mountains. The floor of the Sacramento Valley is relatively flat, with elevations ranging from about 60 to 300 feet above sea level. This area is characterized by hot dry summers and mild winters. Precipitation is relatively light, ranging from 15 to 20 inches per year as far north as Red Bluff, falling mostly as rain. The mountainous areas bordering the valley reach elevations of over 5,000 feet and receive much more precipitation, with snow prevalent at higher elevations. Areas at elevations above 5,000 feet receive an average of 42 inches of precipitation per year, and as much as 90 inches falls at Lassen Peak.

The upper portion of the Sacramento River is fed by tributary flows from numerous small creeks, primarily those draining the western slopes of the Cascade and Sierra Nevada mountains. The volume of flow increases as the river progresses southward, and is increased considerably by the contribution of flows from the Feather River and the American River watersheds. Accordingly, the Sacramento River is characterized in two sections: the upper section from its source to just above its confluence with the Feather River, and the lower section from the confluence with the Feather River to the Delta.

TABLE II-3
MAJOR SURFACE WATER RESERVOIRS

Reservoir (Dam)	River or Watershed	CVP Division (if applicable)	Capacity (1,000 acre-feet)	Year Complete	Owner
Trinity River Basin					
Clair Engle	Trinity	Trinity River	2,448	1962	Relamation
Sacramento River Basin					
Whiskeytown	Clear Creek	Trinity River	241	1963	Relamation
Shasta	Sacramento	Shasta	4,552	1945	Relamation
Black Butte	Stony Creek		144	1963	COE
Almanor	Feather		1,143	1927	PG&E
Bucks	Feather		106	1928	PG&E
Oroville	Feather		3,538	1968	DWR
New Bullards Bar	Yuba		966	1970	YCWA
Camp Far West	Bear		104	1963	SSWD
French Meadows (L.L. Anderson)	American		136	1965	PCWA
Hell Hole	American		208	1966	PCWA
Union Valley	American		277	1963	SMUD
Folsom Lake	American	American River	977	1956	Relamation
San Joaquin River Basin					
Edison	San Joaquin		125	1954	SCE
Mammoth Pool	San Joaquin		123	1960	SCE
Shaver	San Joaquin		135	1927	SCE
Millerton (Friant)	San Joaquin	Friant	520	1947	Relamation
Hensley (Hidden)	Fresno	East Side	90	1978	COE
Eastman (Buchanan)	Chowchilla	East Side	150	1975	COE
McClure (New Echequer)	Merced		1,024	1967	MID
Lloyd Lake (Cherry Valley)	Tuolumne		269	1956	CCSF
Hetch Hetchy (O'Shaughnessy)	Tuolumne		360	1923	CCSF
New Don Pedro	Tuolumne		2,030	1971	TID-MID
New Melones	Stanislaus	East Side	2,420	1979	Relamation
New Hogan	Calaveras		317	1963	COE
Salt Springs	Mokelumne		142	1931	PG&E
Pardee	Mokelumne		210	1929	EBMUD
Camanche	Mokelumne		417	1963	EBMUD
San Luis	N/A	West San Joaquin	2,039	1967	Relamation/DWR
Tulare Lake Basin					
Wishon	Kings		128	1958	PG&E
Courtright	Kings		123	1958	PG&E
Pine Flat	Kings		1,000	1954	COE
Kaweah (Terminus)	Kaweah		143	1962	COE
Success	Tule		82	1961	COE
Isabella	Kern		568	1953	COE

TABLE II-3. CONTINUED

Reservoir (Dam)	River or Watershed	CVP Division (if applicable)	Capacity (1,000 acre-feet)	Year Complete	Owner

Reservoir Owners

CCSF:	City and County of San Francisco
COE:	U.S. Army Corps of Engineers
DWR:	California Department of Water Resources
EBMUD:	East Bay Municipal Utility District
MID:	Modesto Irrigation District
SCE:	Southern California Edison Company
PCWA:	Placer County Water Agency
PG&E:	Pacific Gas and Electric Company
SMUD:	Sacramento Municipal Utility District
SSWD:	South Sutter Water District
TID-MID:	Turlock Irrigation District and Modesto Irrigation District
Relamation	U.S. Bureau of Reclamation
YCWA:	Yuba County Water Agency

NOTE:
Reservoirs with capacities exceeding 100,000 acre-feet, except Hensley and Success lakes.
SOURCE:
DWR, 1995.

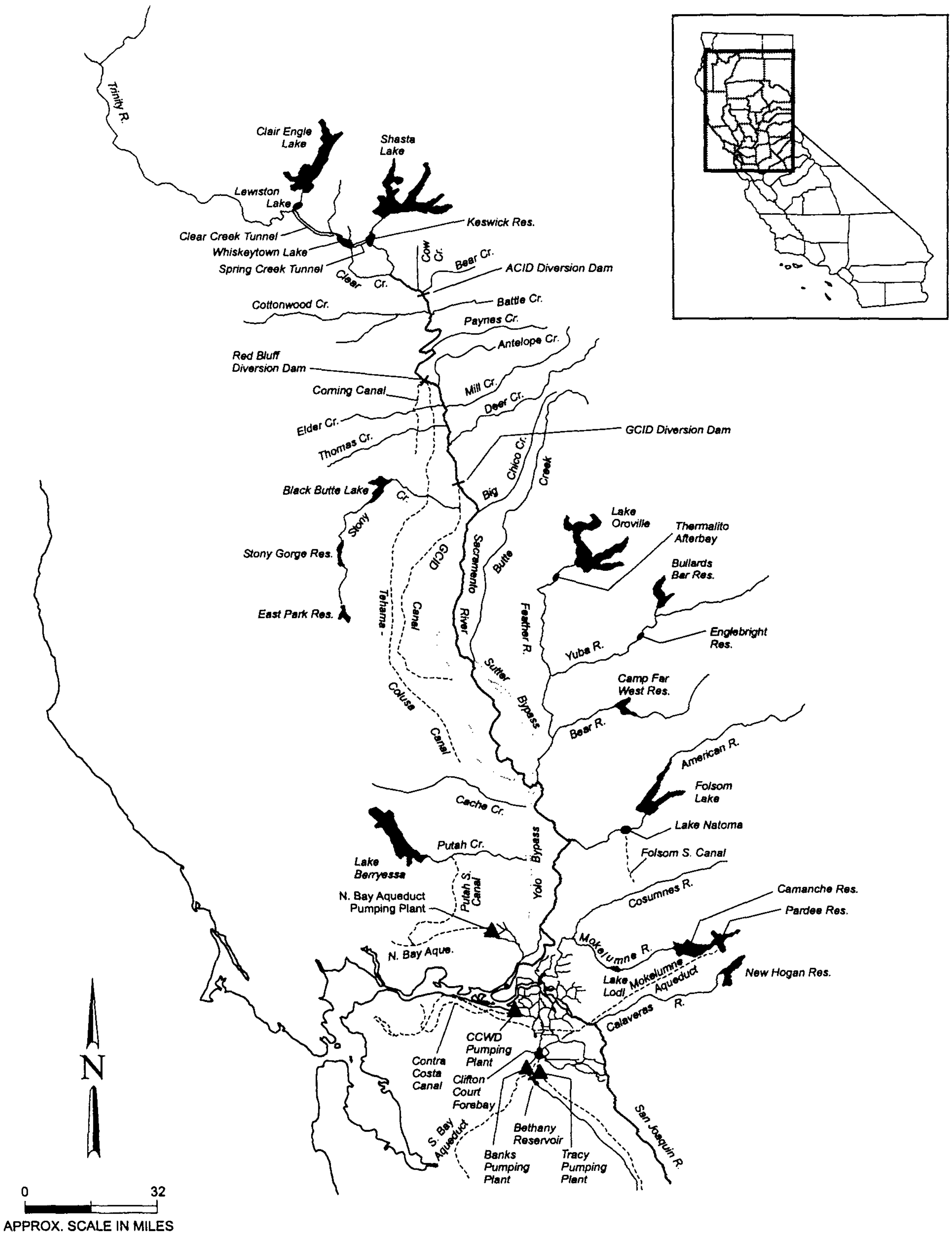


FIGURE II-2

SACRAMENTO RIVER BASIN

UPPER SACRAMENTO RIVER

Flows in the upper Sacramento River are regulated by the CVP Shasta Dam (completed in 1945) and re-regulated approximately 15 miles downstream at Keswick Dam (completed in 1950). The portion of the river above Shasta Dam drains approximately 6,649 square miles and produces average annual runoff of approximately 5.7 million acre-feet. As the Sacramento River nears Red Bluff, flows become more influenced by the inflow from major tributary streams, including Clear, Cow, Bear, Cottonwood, Battle and Paynes creeks.

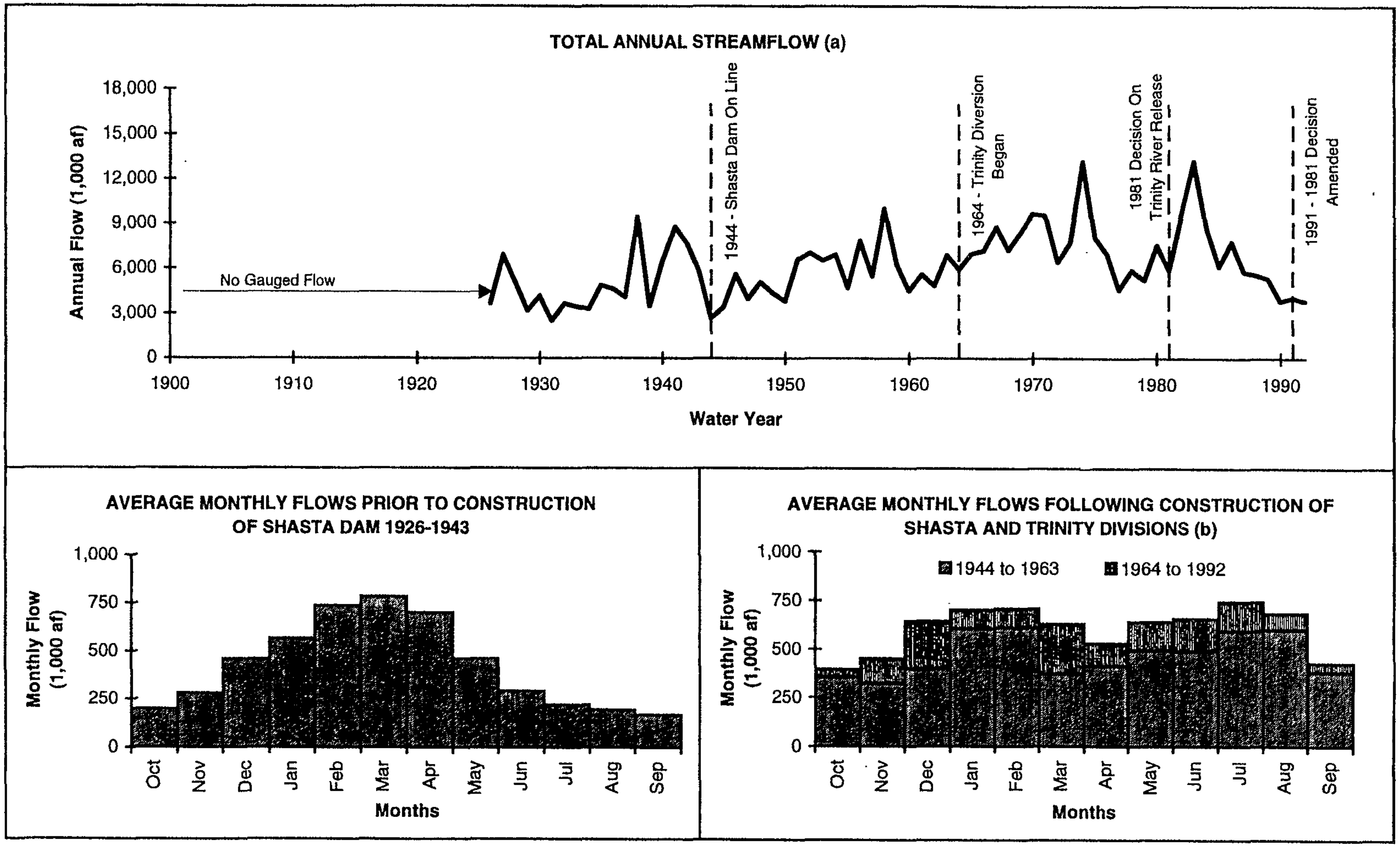
Keswick to Red Bluff

Flows in the section of the Sacramento River between Keswick Dam and the City of Red Bluff are highly regulated by the CVP Shasta Dam, and re-regulated approximately 15 miles downstream at Keswick Dam. As the river nears Red Bluff, however, flows become more influenced by tributary inflow. Major tributaries to the Sacramento River above Red Bluff include Clear, Cow, Bear, Cottonwood, Battle and Paynes creeks.

Water supply facilities that affect flow conditions on the upper Sacramento River above Red Bluff include CVP and local irrigation district facilities. The most significant feature is Shasta Lake, the largest reservoir in the CVP with a storage capacity of 4,552,000 acre-feet. Keswick Dam, completed in 1950 as part of the CVP, has a storage capacity of 23,800 acre-feet and serves as an afterbay for the Shasta and Spring Creek powerplants.

Since 1964, a portion of the flow from the Trinity River Basin has been exported to the Sacramento River Basin through CVP facilities. Water is diverted from the Trinity River at Lewiston Dam via the Clear Creek Tunnel, and passes through the Judge Francis Carr Powerhouse as it is discharged into Whiskeytown Lake on Clear Creek. From Whiskeytown Lake, water is released through the Spring Creek Power Conduit to the Spring Creek Powerplant, and into Keswick Reservoir. All of the water diverted from the Trinity River, plus a portion of Clear Creek flows, are diverted through the Spring Creek Power Conduit into Keswick Reservoir. Spring Creek also flows into the Sacramento River and enters at Keswick Reservoir. Flows on Spring Creek are partially regulated by the Spring Creek Debris Dam. Historically, an average annual quantity of 1,269,000 acre-feet of water has been diverted from Whiskeytown Lake to Keswick Reservoir (1964-1992). This annual quantity is approximately 17 percent of the flows measured in the Sacramento River at Keswick.

Figure II-3 shows the annual flows in the Sacramento River at Keswick from 1926 to 1992. Prior to the construction of Shasta Dam, monthly flows reflected the runoff patterns associated with winter precipitation and spring snow melt. Peak flows generally occurred during the months of February, March, and April. Following the construction of Shasta Dam, average monthly flows during March and April were reduced, and average monthly flows during the summer irrigation months were increased. Following the construction of the Trinity River Division of the CVP in 1964, exported water from the Trinity River Basin to the Sacramento River Basin increased average releases from Keswick Dam on an annual basis.



NOTE: (a) First full year of stream flow data for station 11370500 was 1939. Data for 1926-1963 are from Station 1136950 (Sacramento River at Kennet); data for 1964-1992 from USGS Station11370500 (National Stream Quality Network Station).

(b) Upper portion of bar represents incremental increase in average monthly flows since 1964 water year, when releases through Spring Creek Powerplant began.

FIGURE II-3

HISTORICAL STREAMFLOW IN THE SACRAMENTO RIVER BELOW KESWICK DAM

Water is diverted for agricultural and M&I uses at several locations on the Sacramento River below Keswick. The Wintu Pumping Plant downstream of Keswick began operation in 1966 as part of the CVP. This plant lifts water from the Sacramento River into the Bella Vista Conduit, which carries it to users in the area east of Redding for agricultural and M&I purposes. The Anderson-Cottonwood Irrigation District (ACID) maintains a flashboard and buttress diversion dam across the Sacramento River near Redding. Since 1916, water has been diverted into the ACID canal for irrigation along the west sides of the Sacramento River between Redding and Cottonwood. Typically, flashboards are installed during April and remain in place through October. The Red Bluff Diversion Dam, completed in 1964 as part of the CVP, is located approximately 2 miles south of the City of Red Bluff. The dam diverts water from the Sacramento River into the Tehama-Colusa and Corning canals, which deliver water to 200,000 acres in Tehama, Glen, Colusa, and Yolo counties. The Glenn-Colusa Irrigation District (GCID) supplies water from the Sacramento River near Hamilton City to about 175,000 acres. The GCID canal has been in service since the early 1900s; the existing pumping plant began operation in 1984.

The Sacramento River enters the Sacramento Valley about 5 miles north of Red Bluff. Over the 98 miles between Red Bluff and Colusa, the river is a meandering stream, migrating through alluvial deposits between widely spaced levees. Major streams entering the Sacramento Rivers in this reach include Antelope, Elder, Mill, Thomes, Deer, Stony, Big Chico, Butte creeks, and the Colusa Basin Drain.

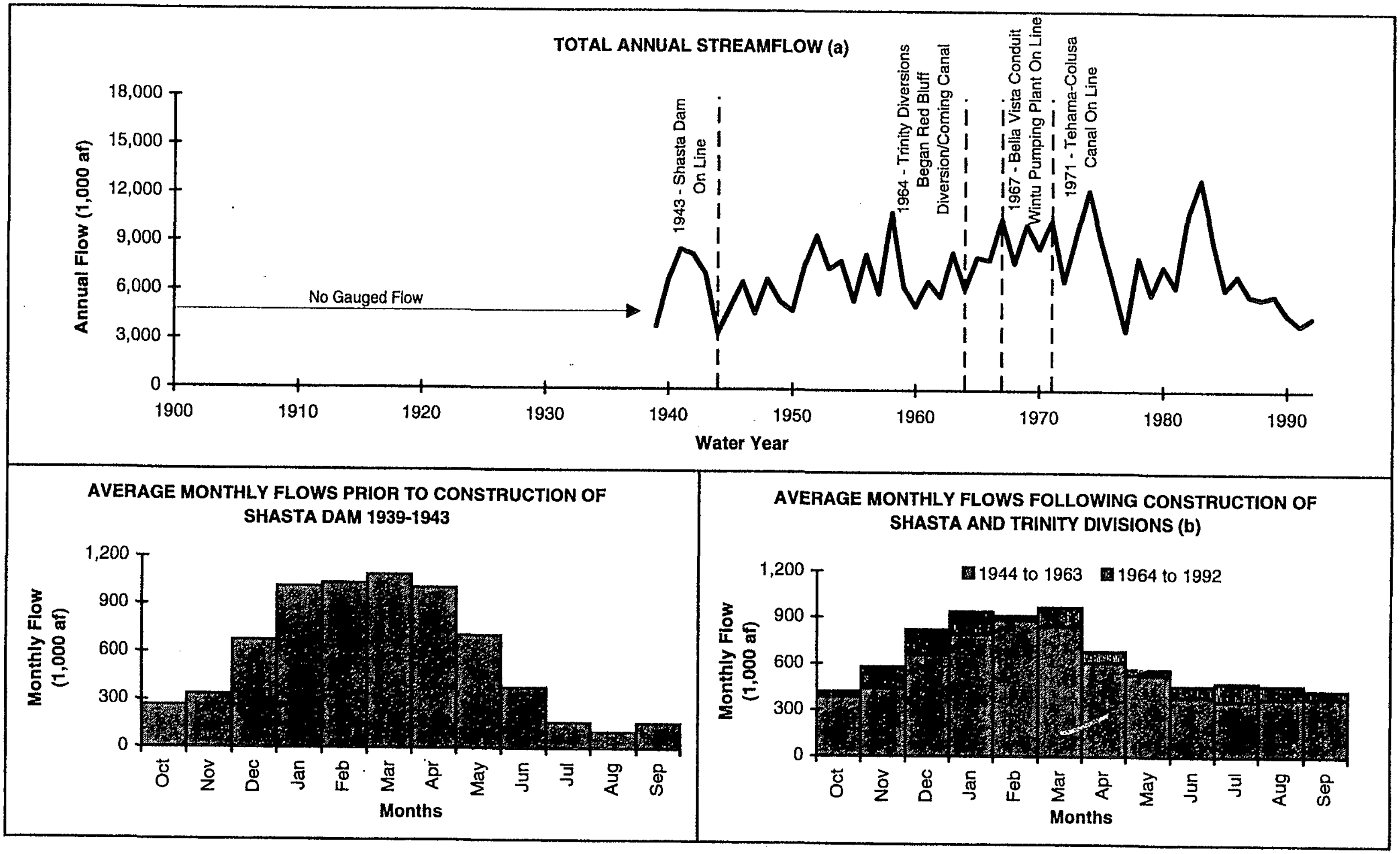
At Wilkins Slough, located above the confluence with the Feather River, the Sacramento River drains a total area of approximately 12,926 square miles. As shown in Figure II-4, a greater proportion of the annual flow at this location occurs during the months of December and January, as compared to flows below Keswick Dam (Figure II-3), because of rainfall runoff from more than 31 tributaries that enter the Sacramento River. Most of the streams tributary to the Sacramento River above the confluence with the Feather River are uncontrolled, other than by hydroelectric facilities.

Flood control along the upper Sacramento River is provided through an extensive series of levees, overflow weirs, pumping plants, and bypass channels. During periods of high flow, overflows from the Sacramento and Feather rivers are conveyed in the Sutter and Yolo bypasses.

Over 50 surface water diversions have been identified along the reach of the Sacramento River between Keswick Dam and Wilkins Slough. Riparian water use between Keswick and Red Bluff averaged 154,900 acre-feet annually between 1922 and 1980 (Reclamation et al., 1990). From Red Bluff to Knights Landing (approximately 18 miles downstream of Wilkins Slough), estimated riparian water use averaged 1,244,400 acre-feet per year.

Upper Sacramento River Tributaries

The portion of the upper Sacramento River between Keswick Dam and Knights Landing (upstream of the confluence with the Feather River) is fed by several tributaries that drain the west slope of the Sierra Nevada Mountains and the east slope of the Coast Range. Many of these



NOTE: (a) First full year of stream flow data available in 1939.
(b) Upper portion of bar represents incremental increase in average monthly flow since 1964, when diversions from Trinity River began.

FIGURE II-4

HISTORICAL STREAMFLOW IN THE SACRAMENTO RIVER BELOW WILKINS SLOUGH

streams contribute significantly to the flow in the Sacramento River. The following descriptions of tributaries follow the order in which they enter the Sacramento River from north to south.

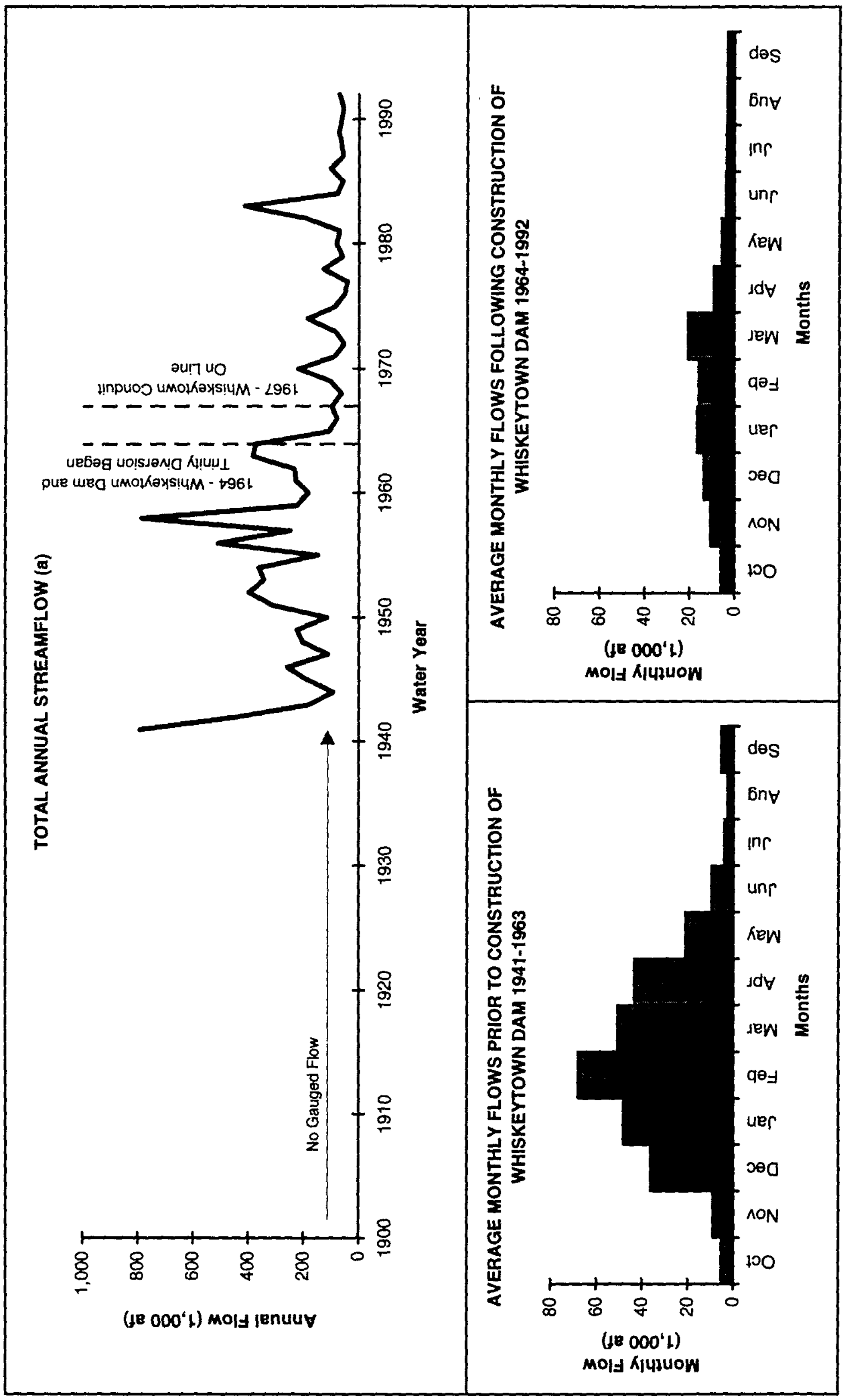
Clear Creek. Clear Creek, the northernmost major tributary to the Sacramento River below Keswick Dam, originates in the mountains between the Sacramento River and Trinity River basins and drains approximately 228 square miles. It flows southwesterly approximately 35 miles to its confluence with the Sacramento River just south of the City of Redding. The median historical unimpaired runoff is approximately 69 thousand acre-feet, with a range of 0 to 491 thousand acre-feet.

Since 1963, flow in Clear Creek has been regulated by the operation of Whiskeytown Dam, which is located approximately at river mile (RM) 16.5. This dam was constructed and is operated by Reclamation as part of the CVP. Whiskeytown Lake, which is formed by the dam, has a storage capacity of 241,000 acre-feet and regulates runoff from Clear Creek and diversions from the Trinity River Basin via the Clear Creek Tunnel. As the exported water from the Trinity River basin enters Whiskeytown Lake, it passes through the Judge Francis Carr Powerhouse. The average annual discharge into Whiskeytown Lake from the powerhouse from 1963 to 1992 was 1,025,000 acre-feet. Releases from Whiskeytown Lake are made primarily to the Spring Creek Tunnel, which conveys water through the Spring Creek Power plant and into Keswick Reservoir on the Sacramento River. Between 1964 and 1992, the average annual generation releases from the Spring Creek Powerplant were 1,269,000 acre-feet. Releases are also made from Whiskeytown Lake to Clear Creek to satisfy instream flow and downstream diversion requirements, and during flood control operations. The effect of Whiskeytown Dam operations on flows in Clear Creek is shown on Figure II-5. This figure illustrates that flows in Clear Creek have been reduced since construction of the dam, as a portion of the runoff in the watershed has been diverted to the Sacramento River along with water exported from Trinity River Basin.

In addition to releases to the Spring Creek Tunnel, water is also diverted from Whiskeytown Lake via the Whiskeytown Conduit to the Clear Creek South Unit of the CVP. This water is used for irrigation in Shasta County, and M&I purposes in the Clear Creek Community Services District of Anderson. The McCormick Saeltzer Dam, constructed in 1903 and located approximately 10 miles downstream from Whiskeytown Dam, diverts water into the Townsend Flat water ditch for irrigation uses.

Cow Creek. Cow Creek originates in the foothills of the Cascade Range, flows southwest, and enters the Sacramento River at RM 280, approximately 4 miles east of the City of Anderson. Cow Creek comprises five tributaries, and drains an area of approximately 425 square miles. Cow Creek contributes approximately 6 to 7 percent of the annual flow to the Sacramento River as measured at Bend Bridge, in response to rain events during the winter. No major storage or diversion structures have been constructed in the Cow Creek watershed, although several small diversions for irrigation, domestic use, and hydroelectric power generation are present.

Bear Creek. Bear Creek originates south of Latour Butte in Shasta County and drains a watershed of approximately 76 square miles. It enters the Sacramento River as a small tributary below the City of Anderson, approximately 4 miles north of the confluence of Battle Creek. The stream has low streamflow in spring through fall of most years, and no flow during periods of



NOTE: (a) First full year of stream flow data available in 1941.
Transbasin diversion from Trinity River into Whiskeytown Lake and diversion to Spring Creek Powerplant began in water year 1964.

FIGURE II-5

HISTORICAL STREAMFLOW IN CLEAR CREEK

below-normal rainfall. No major storage or diversion structures have been constructed in the Bear Creek watershed. During spring and summer, the limited natural streamflow is reduced by unscreened irrigation diversions in the lower reaches where the stream enters the valley floor.

Cottonwood Creek. Cottonwood Creek originates on the eastern slopes of a rugged section of the Coast Ranges in the Yolla-Bolly-Middle Eel Wilderness in Tehama County, at an elevation of approximately 4,000 feet. Cottonwood Creek comprises three tributaries, drains an area of approximately 927 square miles on west side of the Sacramento Valley, and enters the Sacramento river a short distance downstream of the Redding-Anderson area. The creek responds quickly to rainfall, and is prone to flash flooding. Typically, Cottonwood Creek contributes approximately 7 to 8 percent of the flows in the Sacramento River as measured at Bend Bridge, with measurable flows in all months, including during dry years. The ACID canal crosses Cottonwood Creek near the confluence of the North Fork and mainstem, and typically contributes flow to the creek during the irrigation season. No major storage or diversion structures have been constructed along Cottonwood Creek, however, small irrigation diversions are present.

Battle Creek. Battle Creek drains the western flank of Mount Lassen and enters the Sacramento River from the east approximately 5 miles southeast of the town of Cottonwood. It includes two main branches, the North Fork and the South Fork, that drain a water shed of approximately 360 square miles. The two forks join approximately 17 miles above the confluence with the Sacramento River. Battle Creek is the largest spring-fed tributary to the Sacramento River between the Keswick Dam and the Feather River, with a mean September flow of 275 cubic feet per second (cfs). Flows typically remain high throughout the winter and spring and decrease to about half in the summer and fall months. Battle Creek contributes 4 to 5 percent of the annual flow to the Sacramento River, as measured at Bend Bridge.

Flow in Battle Creek is affected by the operation of several facilities, including several power-generation facilities, agricultural diversions, and the Coleman National Fish Hatchery. The power generation projects include several canals that convey water between forks of the river and by-pass portions of Battle Creek. Limited storage capacity for hydropower generation has been developed, and consumptive water uses are low. Consequently, flows at the mouth of Battle Creek as it discharges into the Sacramento River are similar to unimpaired flow conditions, with minor changes resulting from limited upstream storage releases and agricultural diversions.

Paynes Creek. Paynes Creek originates in a series of small lava springs about 6 miles west of the town of Mineral in Tehama County and runs eastward until it flows into the Sacramento River at RM 253, approximately 5 miles north of the City of Red Bluff. It flows into the Sacramento River from the east, draining an area of approximately 93 square miles. Paynes Creek is the southernmost tributary to enter the Sacramento River above the Red Bluff Diversion Dam.

There are no major water storage facilities on Paynes Creek, but as many as 16 small seasonal diversions for irrigation, stock watering and fish culture are present. The largest of these diversions, located approximately 2 miles from the creek's confluence with the Sacramento River, has the capacity to divert approximately 8 cfs of water to irrigate the Bend District.

Antelope Creek. Antelope Creek originates in the Lassen National Forest in Tehama County, flows southwest, and enters the Sacramento River at RM 235, approximately 9 miles south of the City of Red Bluff. The stream flows into the Sacramento River from the east, draining an area of approximately 123 square miles. Two water diversions, located on the valley floor portion of the stream, are operated primarily during the irrigation season. The water rights for these diversions total 120 cfs, exceeding the historical average flow of 92 cfs between April and October. As a result, the lower reach of the stream is usually dry when both diversions are operating.

Elder Creek. Elder Creek begins in the foothills of the Coastal Range, runs eastward into the Central Valley, and ultimately flows into the Sacramento River at RM 230, approximately 12 miles south of the City of Red Bluff. The stream flows into the Sacramento Valley from the west, draining a watershed of approximately 142 square miles. There are no significant dams on Elder Creek, but several small water diversions are present. The stream is generally intermittent with a highly fluctuating flow regime. Flow records indicate peak flows in excess of 11,000 cfs, but the stream is normally dry from July to November.

Mill Creek. Mill Creek is a major tributary to the Sacramento River, flowing from the southern slopes of Mount Lassen and entering the Sacramento River from the east at RM 230, approximately 1 mile north of Tehama. The stream originates at an elevation of approximately 8,000 feet and descends to an elevation of approximately 200 feet near its confluence with the Sacramento River. Mill Creek runs approximately 60 miles in length and drains a watershed of approximately 134 square miles. During the irrigation season, three dams on the lower 8 miles of the stream divert most of the natural flow, particularly during dry years. Mill Creek contributes approximately 2 to 3 percent of the average total annual flow in the Sacramento River, as measured at Bend Bridge.

Thomes Creek. Thomes Creek originates in the foothills of the Coastal Range, travels eastward into the valley, and flows into the Sacramento River at RM 224 approximately 4 miles north of the city of Corning. It drains a watershed of approximately 203 square miles, and contributes 2 to 3 percent of the flows in the Sacramento River as measured at Bend Bridge, based on historical records. No significant dams are located on Thomes Creek, other than two seasonal diversion dams, one near Paskenta and one near Henleyville. In addition, several small pump diversions are operated seasonally in the stream. Below the USGS stream gauge near Paskenta, the stream is generally dry or flows intermittently from mid-summer until the first heavy fall rains.

Deer Creek. Deer Creek is a major tributary to the Sacramento River that originates from several small springs near Childs Meadows to the north and from the southern slopes of Butt Mountain to the south. It enters the Sacramento River from the east at RM 220, approximately 1.5 miles north of the Woodson Bridge State Park. The stream is approximately 60 miles in length, draining a watershed of about 210 square miles. Along the lower 10 miles of the stream, which flows through the Sacramento Valley, three diversion dams and four diversion ditches divert all of the natural flow from mid-spring to fall in some years. Deer Creek flows typically contribute approximately 2 to 3 percent of the average total flow in the Sacramento River flows as measured at Bend Bridge.

Stony Creek. Stony Creek is a westside stream that originates on the eastern slope of the Coastal Range and runs northeasterly until it joins the Sacramento River south of Hamilton City in Glenn County. The creek drains a watershed area of approximately 738 square miles.

Flows in Stony Creek are controlled by East Park Dam and Reservoir and Stony Gorge Dam, which are part of the Orland Project, and farther downstream by the Black Butte Dam. East Park and Stony Gorge reservoirs store surplus water for irrigation deliveries and are operated by Reclamation independently of the CVP. Black Butte Dam and Reservoir were constructed by, and are maintained and operated by the COE; they provide flood control and irrigation supply. Black Butte is financially integrated and operationally coordinated with the CVP.

The GCID canal, which crosses Stony Creek downstream of Black Butte Dam, includes a seasonal gravel dam constructed across the creek on the downstream side of the canal. This crossing allows the canal to convey water south of Stony Creek during the irrigation season, and captures up to the entire flow of Stony Creek during the irrigation season.

Big Chico Creek. Big Chico Creek originates on Colby Mountain in the northern Sierra Nevada at an elevation of approximately 6,000 feet. The creek flows southwest for approximately 45 miles, drains a watershed area of 72 square miles, and enters the Sacramento River from the east at RM 193, about 5 miles west of the City of Chico. Two water diversion dams are located on Big Chico Creek; Five-Mile Diversion, located upstream of the City of Chico, and One-Mile Diversion, located downstream of the City of Chico. During the summer months (June - October), the base flow in Big Chico Creek above Five-Mile Diversion is typically 20 to 25 cfs. Most of this flow is lost to infiltration in the region of the creek's outwash fan, located approximately in the City of Chico. As a result, in most years, late summer surface flow does not extend downstream of Rose Avenue.

The M&T pumping station, located near the confluence with the Sacramento River, is the main diversion on Big Chico Creek. These pumps have the capacity to divert 135 cfs from the creek for use at the M&T Ranch and on lands managed by DFG, the Service, and The Nature Conservancy.

Butte Creek. Butte Creek originates in the Jonesville Basin, Lassen National Forest, on the west slope of the Sierra Nevada at an elevation of approximately 6,500 feet. The stream drains a watershed of approximately 150 square miles, and enters the Sacramento River from the east at Butte Slough (RM 139) between Colusa Weir and Tisdale Bypass. Water in Butte Creek also enters the Sacramento River through the Sutter Bypass and Sacramento Slough at RM 80.

During flood events, peak flood flows on the Sacramento River are diverted into Butte Creek at various locations between the mouth of Big Chico Creek and the reclamation district pumps near Princeton. Two such inflow points are the Moulton Weir Bypass and the Colusa Weir Bypass.

Several small tributaries, such as Middle Butte Creek and Little Butte Creek, flow into Butte Creek in the upper watershed area. Water is imported from the Feather River Basin for hydropower generation at DeSabla Forebay on Middle Butte Creek, which receives water from the West Branch of the North Fork Feather River via the Toadtown Canal. The Feather River flows diverted into Butte Creek through Toadtown Canal averaged 42,470 acre-feet annually between 1987 and 1992. Agricultural diversions also convey water from the Feather River, Big Chico Creek, and Little Chico Creek into Little Butte Creek.

Numerous storage and diversion facilities have been constructed along Butte Creek. The major flow regulating facilities include Paradise Dam and Magalia Dams on Little Butte Creek, and the Centerville Diversion Dam on Butte Creek, which diverts a large portion of the flow to the Centerville Powerplant.

Colusa Basin Drain. The Colusa Basin Drain provides drainage for a large portion of the irrigated lands on the western side of the Sacramento Valley and supplies irrigation water to lands in this area. The drain is bounded on the west by the Coastal Range, on the east by the Sacramento River, and by Stony and Cache creeks on the north and south. The drainage area encompasses approximately 1,500 square miles in Glenn, Colusa, and Yolo counties. Of this area, approximately 570 square miles are within the watersheds of various westside tributaries, and the remainder are located in the relatively flat valley bottom. The watershed contains 67 individual streams, including forks and branches; approximately 11 of these currently flow directly into the Colusa Basin Drain.

Historically, the area within the basin was subject to periodic flooding from the Sacramento River. Flows in the basin generally discharged to the river in a southeasterly direction through a series of sloughs. Reclamation efforts begun during the 1850's eventually drained much of the wetland area and provided agricultural lands. Levees along the west bank of the Sacramento River block the natural drainage of the westside tributaries, and route these flows though the Colusa Basin Drain to the Sacramento River via outfall gates at Knights Landing. At times when Sacramento River levels are higher than those in the drain, gravity diversion of river flows into the drain is possible, supplementing irrigation supplies. The Knights Landing Ridge Cut, the lower 7 miles of the drain, provides an outlet for flood flows to the Yolo Bypass.

During the spring, summer, and fall, flows in the drain consist of natural runoff and return flows from surrounding irrigated lands. Diversions along the drain primarily supply water to agricultural lands in the area as well as to the Sacramentò, Delevan, and Colusa National Wildlife Refuges (NWRs).

LOWER SACRAMENTO RIVER AND TRIBUTARIES

The lower Sacramento River is identified as the reach that extends from Knights Landing, just above the confluence with the Feather River, to Freeport, just below the point where the Sacramento River enters the legal Delta boundary. The drainage area of the Sacramento River upstream of Freeport encompasses more than 24,000 square miles. The historical average annual flow on the Sacramento River at Freeport is approximately 16.7 million acre-feet per year, more than twice the average annual flow measured below Wilkins Slough over the same time period.

The flows in this portion of the Sacramento River are increased primarily by the addition of the Feather and American river flows. The combined flows of the Feather River and Sutter Bypass enter the Sacramento River near Verona. During high flows, Sacramento River water is diverted into the Yolo Bypass via Fremont Weir near Knights Landing and the Sacramento Weir near West Sacramento. The Yolo Bypass is a low-lying area of about 40,000 acres west of the Sacramento River that conveys flood flows from the Sacramento River and local runoff from Cache and Putah creeks to the Sacramento River about 10 miles above Collinsville. Smaller contributions to this section of the Sacramento River are made by the Cross Canal, draining the area from the Feather River east to Auburn and Roseville, and the Colusa Basin Drain, which drains the west side of the Sacramento Valley from about Willows south to Knights Landing.

Feather River and Tributaries

The Feather River, with a drainage area of 3,607 square miles on the east side of the Sacramento Valley, is the largest tributary to the Sacramento River below Shasta Dam. The Feather River enters the Sacramento River from the east at Verona. The median historical unimpaired runoff of the Feather River watershed is 3.8 million acre-feet per year, with a range of 1.0 to 9.4 million acre-feet per year. This total flow is provided by the Feather River and tributaries, which include the Yuba and Bear rivers.

Flows on the Feather River are regulated by Oroville Dam, the lowermost reservoir on the river, which began operation in 1967 as part of the SWP. Oroville Reservoir, which is created by Oroville Dam at the confluence of the West Branch and the North, Middle, and South forks, has a storage capacity of approximately 3.5 million acre-feet per year. Water released from Oroville Dam is diverted approximately 5 miles downstream at the Thermalito Diversion into the Thermalito Power Canal, thence to the Thermalito Forebay, and finally into the Thermolito Afterbay. Some of the units in the Thermalito and Hyatt powerhouses are reversible, enabling pumping from the afterbay back into Lake Oroville.

Approximately 40 diversions have been identified along the Feather River. Four of the major diversions take water at the Thermalito Afterbay: Western Canal, Richvale Canal, the Pacific Gas and Electric Lateral, and the Sutter-Butte Canal. Some of the water diverted into these canals is exported to the Butte Creek watershed. These canals diverted an average of approximately 770,000 acre-feet per year for the period between water year 1968 and 1992. Riparian water use along the Feather River increased from approximately 454,000 acre-feet per year in the 1920s to an average of 890,000 acre-feet per year in the 1970s (Reclamation et al., 1990). This is a nearly twofold increase in riparian water use, or an increase from 11 percent to over 26 percent of the historical average annual flow in the river as measured at Oroville.

Between the Thermolito Diversion Dam and the Thermalito Afterbay, flows in the Feather River are maintained at a constant 600 cfs. This 8-mile section of the river is often referred to as the "low flow" section. The Thermolito Afterbay serves the dual purposes of an afterbay to re-regulate releases to the Feather River from the hydroelectric plants and a warming basin for irrigation water that will be diverted to rice fields. Consequently, the water temperatures in the approximately 14-mile section of the Feather River below Thermalito Afterbay, commonly referred to as the "high flow" section, are higher than water temperatures in the "low flow" section.

Figure II-6 shows the distribution of annual flows in the Feather River downstream from Oroville Dam for the period between 1902 and 1992. Prior to the construction of Oroville Dam, flows in the Feather River reflected natural runoff conditions, with peak flows in the months of March, April, and May. Following the construction of Oroville Dam, the average monthly flow pattern was modified to provide reduced flows during the spring months and increased flows during summer months.

The operation of several reservoirs affects the flow on the portion of the Feather River upstream of Oroville Reservoir. The largest of these is Lake Almanor on the North Fork Feather River, with a storage capacity of 1.3 million acre-feet per year. Other impoundments in the Feather River drainage area above Oroville Reservoir, including Mountain Meadows Reservoir, Bucks Lake, Little Grass Valley Reservoir, Lake Davis, Frenchman Lake, Butt Valley Reservoir, Sly Creek Reservoir, Philbrook Reservoir, and Antelope Lake, provide additional storage capacity of approximately 450,000 acre-feet per year.

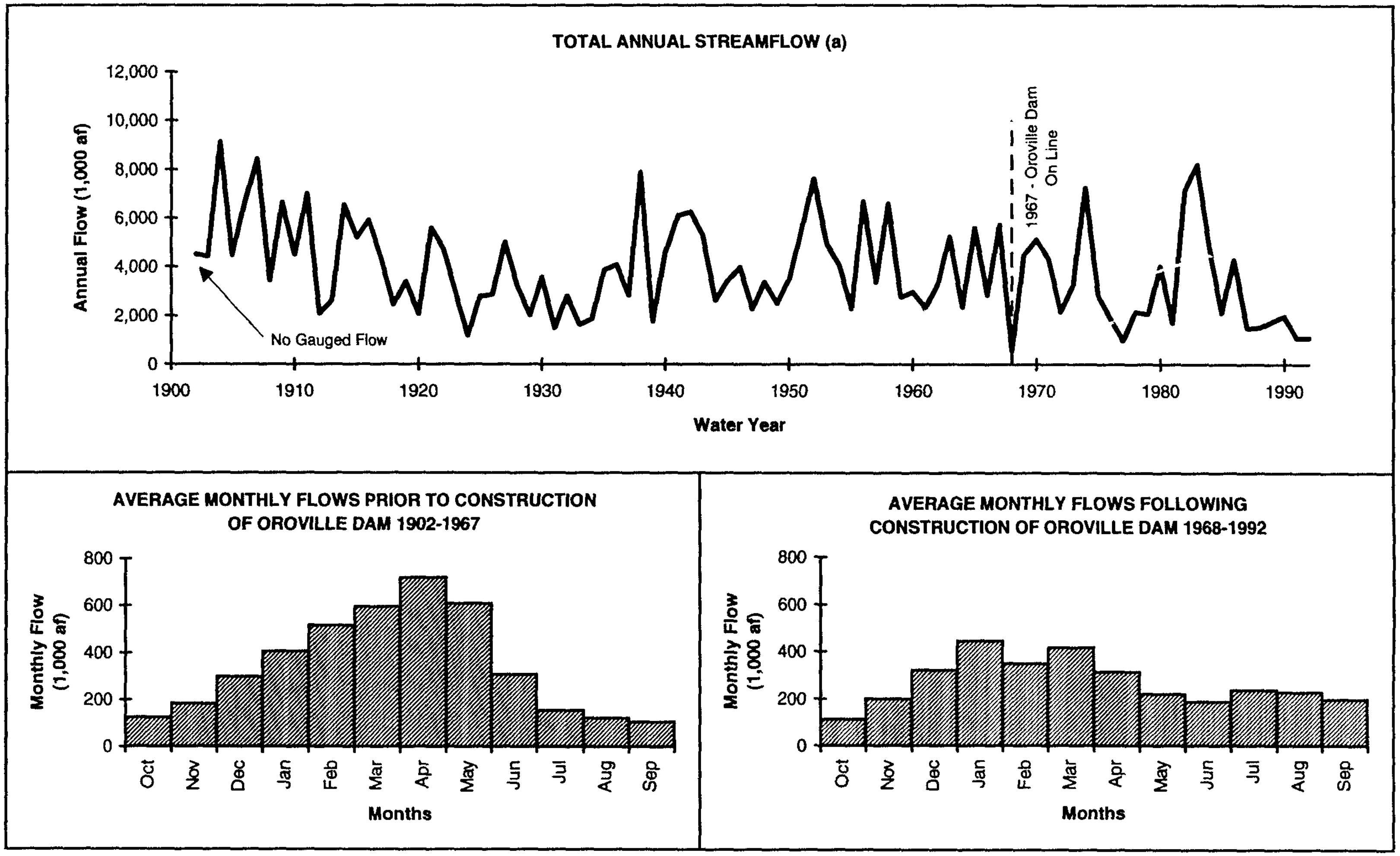
Yuba River. The Yuba River is a major tributary to the Feather River, historically contributing over 40 percent of the flow, on a total annual basis, as measured at Oroville. The Yuba River originates in the Sierra Nevada, drains approximately 1,339 square miles of the eastern Sacramento Valley, and flows into the Feather River near the town of Marysville. The North, Middle, and South forks make up its upper watershed.

The median historical unimpaired runoff in the Yuba River watershed is 2.1 million acre-feet per year, with a range from 0.4 to 4.9 million acre-feet per year. The major reservoir in the watershed, New Bullards Bar Reservoir, is operated by the Yuba County Water Agency, and has a storage capacity of just under 1 million acre-feet per year. This reservoir was completed in 1969 to replace the original Bullards Bar Reservoir, which had a capacity of 31,000 acre-feet per year. Water is diverted from New Bullards Bar through the Colgate Tunnel into the Colgate Powerhouse, located downstream on the North Yuba River. As compared to flow conditions prior to the construction of New Bullards Bar Dam, this operation has resulted in reduced flows during the spring months and increased flows during summer months. The 0.2-mile stretch of river between the dam and the two powerhouses has no flowing water except when the reservoir is spilling.

Other small- to medium-sized impoundments in the watershed, including Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Reservoir, Lake Fordyce, and Scotts Flat Reservoir, provide an additional storage capacity of approximately 475,000 acre-feet per year.

Englebright Reservoir is impounded by Narrows Dam, which was constructed by the federal government in 1941 as part of the Sacramento River Debris Control Project. The reservoir has a capacity of 70,000 acre-feet per year and releases water for hydroelectric power generation during summer months. Daguerre Point Dam, located 12.5 miles downstream from Narrows Dam, is the major diversion point on the lower Yuba River.

Bear River. The Bear River is the second largest tributary to the Feather River, contributing approximately 16 percent of the average annual flow. The Bear River originates in the Sierra



NOTE: (a) First full year of stream flow data available in 1902. After 1967, flows recorded at gauge 11406920 (Thermalito Afterbay release) were added to give total Feather River flow below Oroville.

FIGURE II-6

HISTORICAL STREAMFLOW IN THE FEATHER RIVER BELOW OROVILLE

Nevada, drains an area of about 292 square miles, and flows southwesterly until it enters the Feather River approximately 3 miles north of the town of Nicolaus. The median historical unimpaired runoff is 272,000 acre-feet per year, with a range of 20,000 to 740,000 acre-feet per year. The largest reservoir in the watershed, Camp Far West Reservoir, is operated by the South Sutter Water District and has storage capacity of 104,000 acre-feet per year. Other smaller impoundments, including Rollins Reservoir and Lake Combie, provide an additional storage capacity of approximately 70,000 acre-feet per year. Eleven powerplants and their associated fore- and afterbays also regulate Bear River flow. Most of these powerplants are owned and operated by PG&E.

As part of the hydroelectric project operations in the Bear River, water is exchanged with the Yuba River and American River basins. Water from the South Fork Yuba River is conveyed by the Drum Canal into the Drum Forebay on the Bear River. The average annual flow through the Drum Canal for the period from 1965 to 1992 was 367,600 acre-feet per year. Water from the North Fork of the American River, diverted through Lake Valley Canal, also flows into the Drum Forebay. For the period between 1965 and 1992, the average annual flow through the Lake Valley Canal was 11,530 acre-feet per year.

From the Drum Forebay, water is diverted to two places. The first is Canyon Creek, where the water either supplies the Alta Powerhouse or flows back into the American River. Portions the Alta Powerhouse discharge may be diverted to the Bear River. The second diversion from the Drum Forebay is to Drum Powerhouses 1 and 2. All of the discharge from these powerplants flows into the Bear River.

Based on 1992 values, it is estimated that more than 90 percent of the inflow from the Drum and Lake Valley canals is diverted to Drum Powerhouses 1 and 2 and into the Bear River. The remainder is diverted to the American River or Alta Powerhouse.

American River

The American River originates in the mountains of the Sierra Nevada range, drains a watershed of approximately 1,895 square mile, and enters the Sacramento River at RM 60 in the City of Sacramento. The American River contributes approximately 15 percent of the total flow in the Sacramento River. The American River watershed ranges in elevation from 23 feet to over 10,000 feet, and receives approximately 40 percent of its flow from snowmelt.

Development on the American River began in the earliest days of the California Gold Rush, when numerous small diversion dams, flumes, and canals were constructed. Currently, 19 major reservoirs in the drainage have a combined storage capacity of 1.9 million acre-feet per year. The largest reservoir in the watershed, Folsom Lake, was formed with the completion of Folsom Dam in 1956, and has a capacity of nearly 1 million acre-feet per year. Folsom Dam, located approximately 30 miles upstream from the confluence with the Sacramento River, is operated by Reclamation as a major component of the CVP. Water released from Folsom Lake is used to generate hydroelectric power, meet downstream water rights obligations, contribute to Delta inflow requirements, and provide water supplies to CVP contractors.

Releases from Folsom Dam are re-regulated approximately 7 miles downstream by Nimbus Dam. This facility is also operated by Reclamation as part of the CVP, and began operation in 1955. Nimbus Dam creates Lake Natoma, which serves as a forebay for diversions to the Folsom South Canal. This CVP facility began operation in 1973, and serves water to agricultural and M&I users in Sacramento and San Joaquin counties.

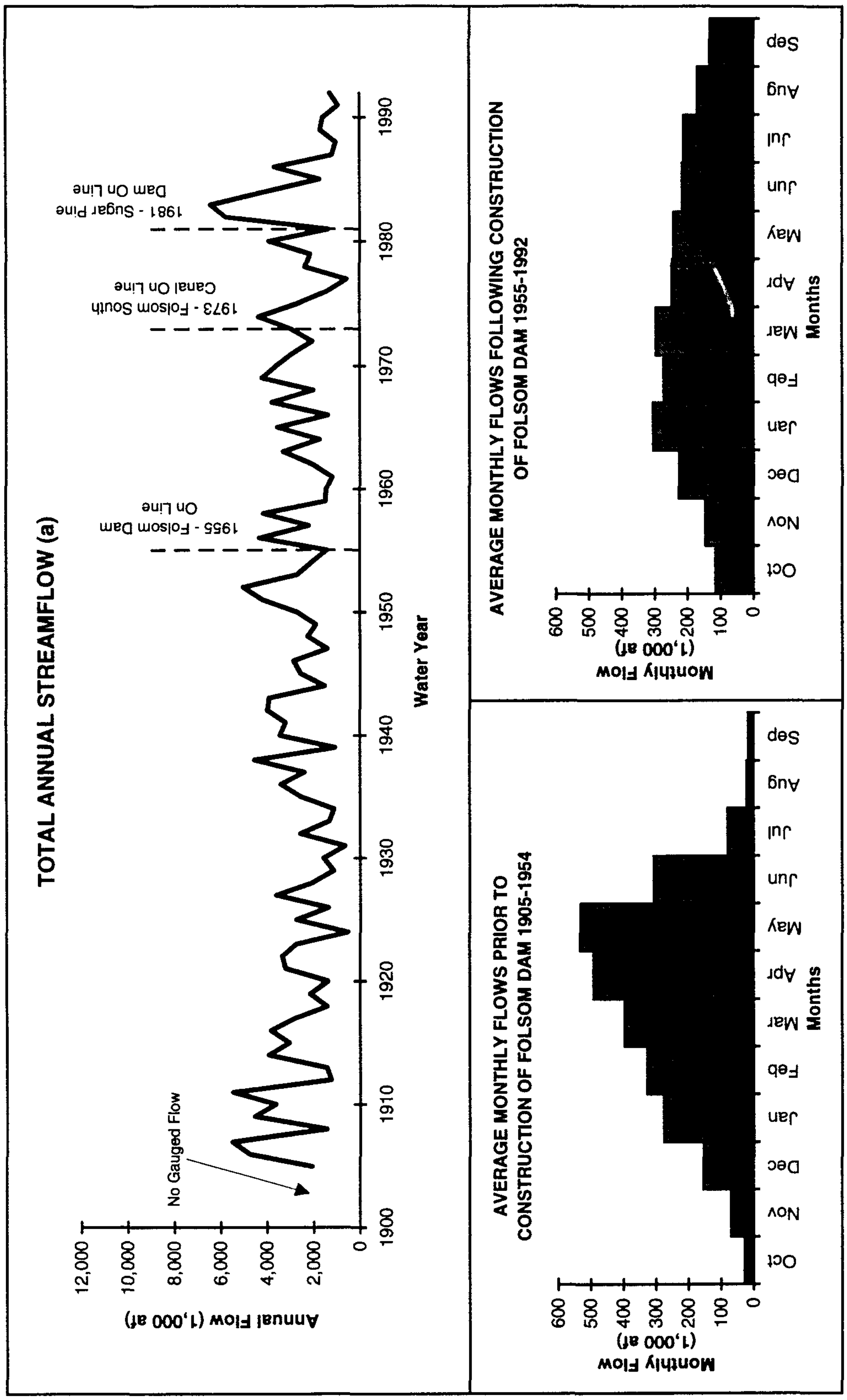
Figure II-7 shows the distribution of average monthly flows in the American River downstream from Nimbus Dam at Fair Oaks, for periods before and after the construction of Folsom Dam. As illustrated in this figure, prior to construction of Folsom Dam, monthly flows were generally highest during the months of April and May, and approached zero in the late summer. In wet years, this high spring flow often resulted in downstream flooding in the Sacramento area. Following the construction of Folsom Dam, the extreme flows in wet years have been reduced, and higher flows have been provided during dry periods. This operation has resulted in improved flood protection to downstream areas.

Although Folsom Lake is the main storage and flood control reservoir on the American River, numerous other small reservoirs in the upper basin provide hydroelectric generation and water supply. None of the upstream reservoirs have any specific flood control responsibilities. The total upstream reservoir storage above Folsom Lake is approximately 820,000 acre-feet per year. Ninety percent of this upstream storage is contained by five reservoirs: French Meadows (136,000 acre-feet per year), Hell Hole (208,000 acre-feet per year), Loon Lake (76,000 acre-feet per year), Union Valley (277,000 acre-feet per year), and Ice House (46,000 acre-feet per year).

French Meadow and Hell Hole reservoirs, located on the middle fork of the American River, are owned and operated by Placer County Water Agency (PCWA). PCWA provides wholesale water to agricultural and urban areas within Placer County. For urban areas, PCWA operates water treatment plants and sells wholesale treated water to municipalities that provide retail delivery to their customers. The cities of Rocklin and Lincoln receive water from PCWA. Loon Lake, also on the middle fork, and Union Valley and Ice House reservoirs on the south fork are all operated by SMUD.

SURFACE WATER QUALITY IN THE SACRAMENTO RIVER BASIN

The reach of the Sacramento River between Keswick Dam and Red Bluff has excellent mineral quality, and the water is therefore suitable for most uses. Most of the water can be classed as calcium-magnesium bicarbonate, and is slightly hard, but does not require softening. The water is excellent to good for irrigation use, and generally mineral levels are satisfactory for most domestic and industrial uses. Many tributaries drain to the upper Sacramento River without deteriorating water quality, indicating the excellent quality of the tributaries. Turbidity levels are generally low, but become elevated occasionally as a result of high flows on Cottonwood Creek, which is highly susceptible to sediment loading during high runoff. The development of regional wastewater treatment plants has resulted in effluent with concentrated nutrient loads from urban areas, particularly from the cities of Redding and Red Bluff. The Sacramento River downstream of Keswick Dam is a designated spawning area for anadromous fish, and has a minimum allowable dissolved oxygen (DO) level of 7 milligrams per liter (mg/l). At the Red Bluff Diversion Dam, the



NOTE: (a) First full year of stream flow data available in 1905. Flows after 1955 also affected by various upstream development activities.

FIGURE II-7

HISTORICAL STREAMFLOW IN THE AMERICAN RIVER BELOW FAIR OAKS

river maintains oxygen levels near saturation, with concentrations that have ranged from slightly below 10 mg/l to over 12 mg/l.

From Red Bluff to the Delta, the Sacramento River is generally of good quality, although water quality is periodically degraded due to the discharge of toxins, untreated sewage, and other nonpoint source contaminants. In the lower reaches of the Sacramento River, water quality is affected by intrusion of saline seawater from the Delta. The upper reaches of major tributaries to the lower Sacramento River, the Feather, Yuba, and American rivers, all have excellent water quality. In the lower Sacramento River, agricultural drainage influences water quality by contributing to increased turbidity, and substantial mineral, nutrient, and herbicide loads. The state agencies and rice growers continue to promote management practices to ensure that discharges from rice fields do not exceed performance goals established by the Central Valley Regional Water Quality Control Board.

SURFACE WATER IN THE SAN JOAQUIN RIVER BASIN

The 250-mile-long San Joaquin Valley comprises the southern two thirds of the Central Valley, and is subdivided between the San Joaquin River Basin and the Tulare Lake Basin. The San Joaquin River watershed includes lands that drain to the San Joaquin River and ultimately flow into the Delta. The Tulare Lake Basin watershed includes lands that drain into Tulare Lake bed or Buena Vista Lake bed. Watersheds in the Tulare Lake Basin are discussed in a subsequent section of this chapter.

The San Joaquin River Basin, shown in Figure II-8, extends from the Sacramento-San Joaquin Delta in the north to the north fork of the Kings River in the south, and from the foothills of the Sierra Nevada to the Coast ranges. It encompasses about 32,000 square miles in the northern part of the San Joaquin Valley, roughly from Fresno to Stockton. The climate of the San Joaquin River Basin is semiarid, characterized by hot, dry summers and mild winters, except at the highest altitudes, with distinct wet and dry seasons. Most of the precipitation falls from November to April, with rain at the lower elevations and snow in the higher regions. On the valley floor, precipitation decreases from north to south, ranging from 14 inches in Stockton to 8 inches at Mendota.

The primary sources of surface water to the basin are rivers that drain the western slope of the Sierra Nevada Range. Each of these rivers, the San Joaquin, Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes, drain large areas of high elevation watershed that supply snowmelt runoff during the late spring and early summer months. Historically, peak flows occurred in May and June and flooding occurred in most years along all of the major rivers. When flood flows reached the valley floor, they spread out over the lowlands, creating several hundred thousand acres of permanent tule marshes and more than 1.5 million acres of seasonally flooded wetlands.

The three northernmost streams, the Calaveras, Mokelumne, and Cosumnes rivers, flow into the San Joaquin River within the boundaries of the Delta. These rivers are commonly referred to as "east side tributaries to the Delta." Streams on the west side of the basin are intermittent and

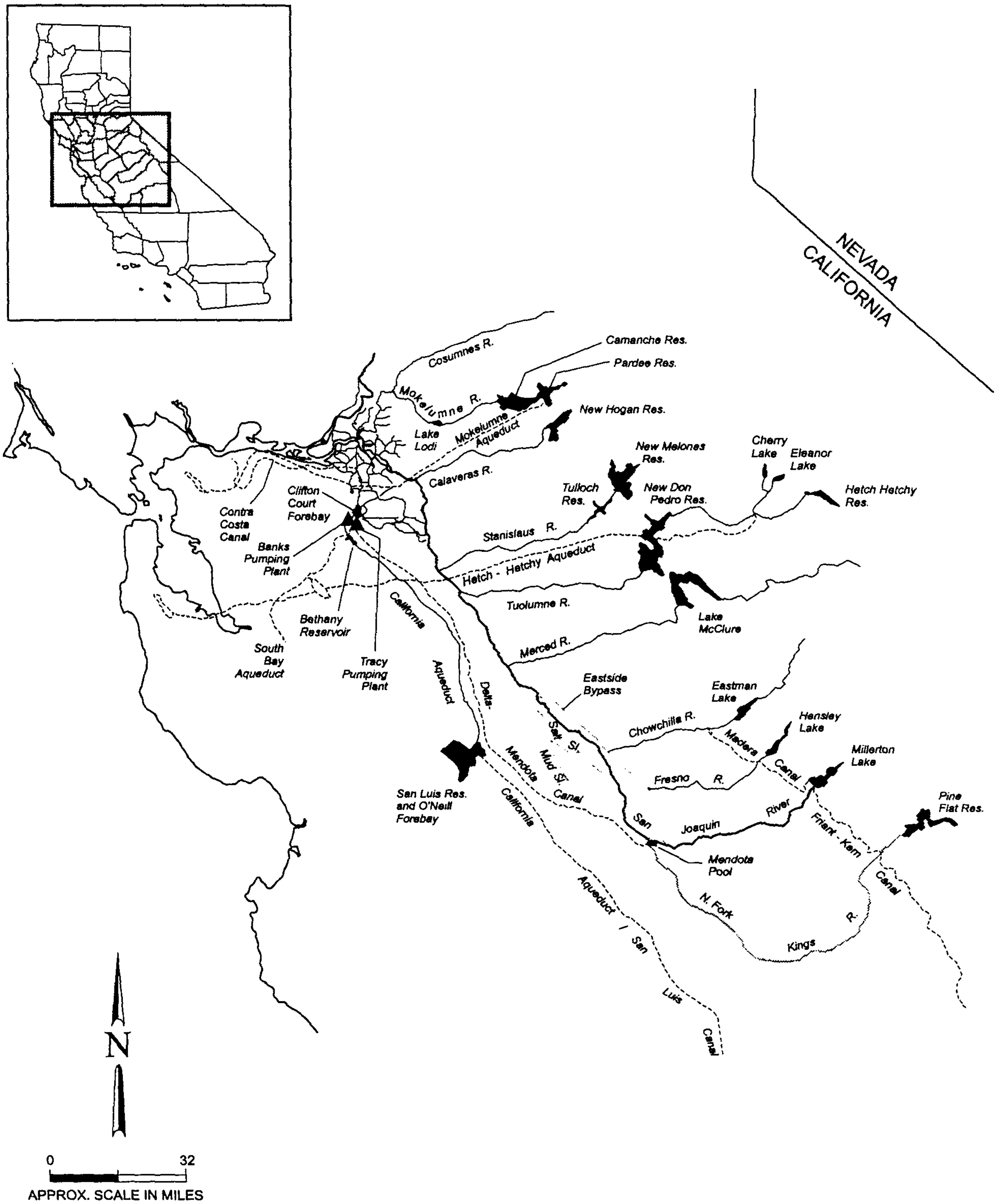


FIGURE II-8

SAN JOAQUIN RIVER BASIN

their flows rarely reach the San Joaquin River. Natural runoff from westside sloughs is augmented with agricultural drainage. The San Joaquin River originates in the Sierra Nevada at an elevation over 10,000 feet and flows into the San Joaquin Valley at Friant. The river then flows to the center of the valley floor, where it turns sharply northward and flows through the San Joaquin Valley to the Delta. Along the valley floor, the San Joaquin River receives additional flow from the Merced, Tuolumne, and Stanislaus rivers.

The San Joaquin River is characterized by two distinct sections: the upper and lower. The upper San Joaquin River section, upstream of the confluence with the Merced River, was historically characterized by the runoff of the San Joaquin River. During the past 100 years, development in this area has resulted in groundwater overdraft conditions, and the river loses much of its flow through percolation. The lower San Joaquin River, from the confluence with the Merced River to the Delta, is characterized by the combination of flows from tributary streams, major rivers, and agricultural drainage water.

UPPER SAN JOAQUIN RIVER AND TRIBUTARIES

San Joaquin River Between Friant Dam and Gravelly Ford

Flows in the upper San Joaquin River are regulated by the CVP Friant Dam, which stores and diverts water to the Madera and Friant-Kern canals for irrigation and M&I water supplies in the eastern portion of the San Joaquin Valley. In the reach between Friant Dam and the Gravelly Ford, flow is influenced by releases from Friant Dam, with minor contributions from agricultural and urban return flows. Releases from Friant Dam are generally limited to those required to satisfy downstream water rights and instream flows. Millerton Lake, formed by Friant Dam, has a capacity of 520,000 acre-feet per year. Above Friant Dam, the San Joaquin River drains an area of approximately 1,676 square miles and has an annual average unimparied runoff of 1.7 million acre-feet per year. The median historical unimpaired runoff is 1.4 million acre-feet per year, with a range of 0.4 to 4.6 million acre-feet per year. Several reservoirs in the upper portion of the San Joaquin River watershed, including Mammoth Pool and Shaver Lake, are primarily used for hydroelectric power generation and have a combined storage capacity of approximately 620,000 acre-feet per year. The operation of these reservoirs affect the inflow to Millerton Lake.

Figure II-9 shows the annual flows in the San Joaquin River below Friant Dam. Since completion of the dam in 1941, the majority of the annual flow has been diverted to the Friant-Kern and Madera canals. Average monthly releases from Friant Dam to the San Joaquin River since 1941 have included minimum releases to satisfy water rights above Gravelly Ford and flood control releases. Approximately 20 small diversions are located between Friant Dam and Gravelly Ford (DWR Bulletin 130).

San Joaquin River Between Gravelly Ford and Fremont Ford

Gravelly Ford, located downstream of Friant Dam, is a sandy and gravelly section of the San Joaquin River that is subject to high losses of river flow. The section of the San Joaquin River between Gravelly Ford and the Mendota Pool, a reach of approximately 17 miles, is generally dry except when releases are made from Friant Dam for flood control.

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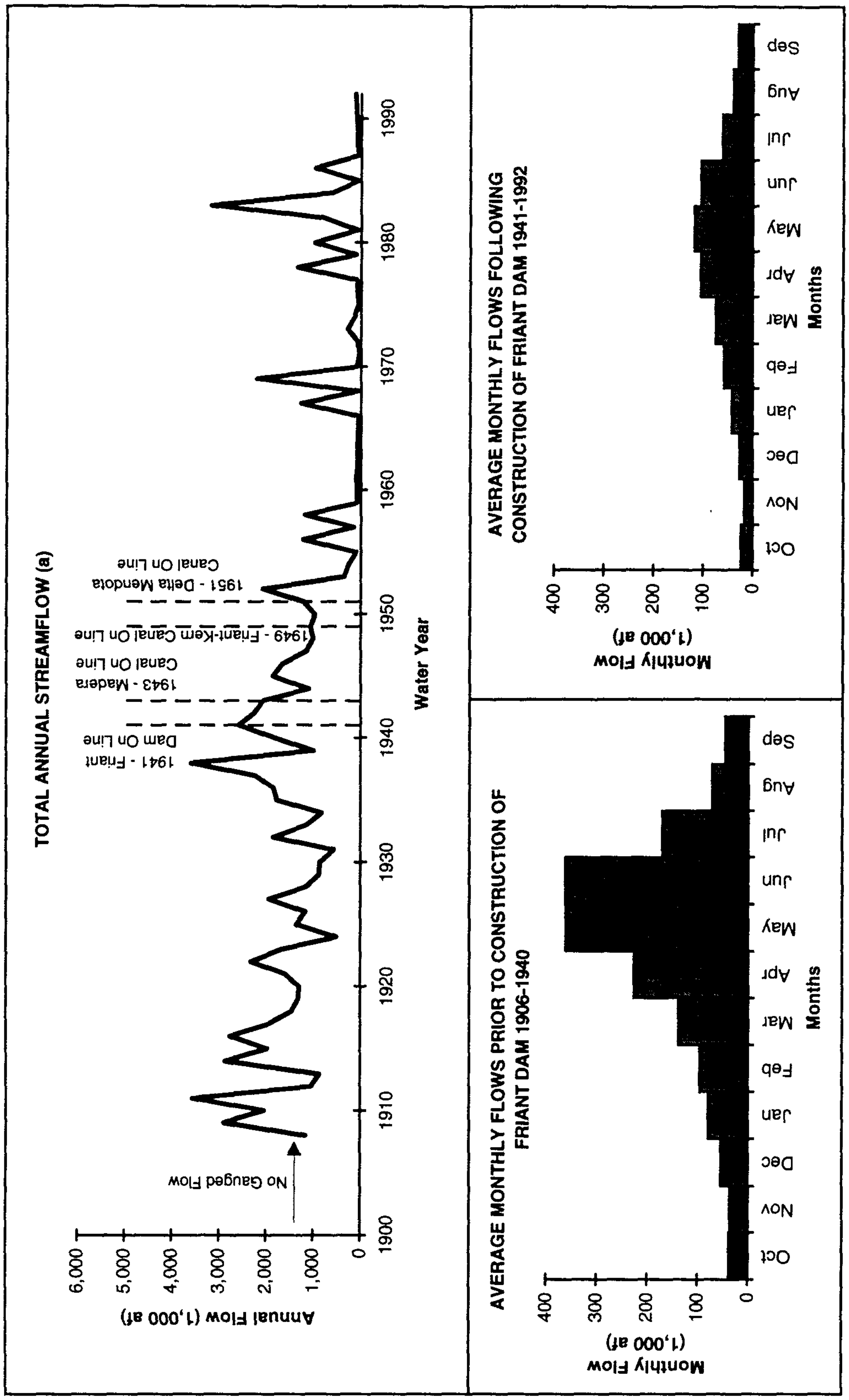


NOTE: (a) First full year of stream flow data available in 1908.
Diversions for irrigation through Madera and Friant-Kern canals began October 1943 and March 1949, respectively.

FIGURE II-9

HISTORICAL STREAMFLOW IN THE SAN JOAQUIN RIVER BELOW FRIANT

During flood control operations, water that passes Gravelly Ford and exceeds demands at Mendota Pool is diverted from the San Joaquin River to the Chowchilla Bypass. When flow in the Chowchilla Bypass reaches its capacity of 6,500 cfs, remaining water in the San Joaquin River flows into the Mendota Pool. The Chowchilla Bypass runs northwest, intercepts flows in the Fresno River, and discharges to the Chowchilla River. The East Side Bypass begins at the Chowchilla River and runs northwesterly to rejoin the San Joaquin River above Fremont Ford. Together, the Chowchilla and Eastside bypasses intercept flows of the San Joaquin, Fresno, and Chowchilla rivers, and other lesser east side San Joaquin River tributaries, to provide flood protection for downstream agricultural lands. These bypasses are located in highly permeable soils, and much of the water recharges groundwater.

Flows in the San Joaquin River that pass the Chowchilla Bypass enter the Mendota Pool. The Mendota Pool was formed in 1871 by the construction of Mendota Dam on the San Joaquin River by water rights holders, and is the point at which the San Joaquin River turns northward. The Mendota Pool has a capacity of approximately 50,000 acre-feet per year and serves as a forebay for diversions to the Main and Outside canals. The Delta-Mendota Canal, which conveys CVP water from the Delta to San Joaquin River Exchange Contractors, terminates at the Mendota Pool. Water also enters Mendota Pool from the south, via Fresno Slough (sometimes referred to as James Bypass), which conveys overflows from the Kings River in the Tulare Lake Basin to the San Joaquin River. Reclamation uses a portion of the flow in Fresno Slough to supply water to the Mendota MWA.

Tributaries to the Upper San Joaquin River

Above Fremont Ford, the San Joaquin River drainage area covers approximately 8,247 square miles. Over 16 riparian diversions have been identified between Gravelly Ford and Fremont Ford by DWR (Bulletin 130-68). These diversions averaged 728,900 acre-feet per year between 1922 and 1980 (Reclamation et al., 1990). Most of these diversions are below Mendota Pool and are currently supplied by water from the Delta-Mendota Canal.

Historically, the San Joaquin River between Gravelly Ford and Fremont Ford received inflow from several large tributaries, including the Fresno and Chowchilla rivers. Now, most of the flow in the Fresno and Chowchilla rivers is diverted and only reaches the San Joaquin River during flooding events. The rest of the time, flow in this reach of the San Joaquin River consists primarily of imported Delta water via the Delta-Mendota Canal which is released from Mendota Pool for subsequent diversion, agricultural returns, and occasional releases from wildlife refuges. Between Sack Dam and the Salt Slough confluence, an approximate reach length of 54 miles, there is usually slight or no flow. Mud and Salt sloughs contribute irrigation return flows to the lower end of this reach. The quality of this water, however, is poor.

Salt Slough and Mud Slough. Salt Slough and Mud Slough are shallow, slow-flowing channels on the west side of the San Joaquin Valley, that primarily convey subsurface agricultural drainage water to the San Joaquin River. During the winter and spring, flows in sloughs consist primarily of a combination of subsurface agricultural drainage, precipitation runoff, and discharges from local duck clubs and wildlife refuges. Summer and fall flows consist primarily of agricultural tailwater, irrigation district spill water, and subsurface agricultural drainage. Following the closure of Kesterson Reservoir and the San Luis Drain in 1985, agricultural drainage from water users on the west side of the San Joaquin Valley was routed through Salt Slough and Mud Slough into the San Joaquin River.

Fresno River. The Fresno River is a tributary to the San Joaquin River that drains a watershed of approximately 237 square miles in foothills of the Sierra Nevada. Because of the relatively low elevation of the watershed, most of the flow in the Fresno River results from rainfall. Historically, the Fresno River has behaved as an ephemeral stream with large winter flood flows and near zero summertime flows. The Fresno River ultimately discharges into the East Side Bypass.

The only regulating reservoir on the Fresno River is Hensley Lake (formed by Hidden Dam), which was completed and operational in 1975, and has a maximum storage capacity of 85,200 acre-feet per year. Hidden Dam is operated by the COE, and releases are coordinated with Reclamation operations at Friant Dam. Madera Canal, which conveys water northwest from Friant Dam, crosses the Fresno River approximately 3 miles downstream from Hidden Dam. Deliveries from Madera Canal to CVP contractors are made via the Fresno River, as are flood spills during flood control operations.

Chowchilla River. The Chowchilla River, a tributary to the San Joaquin River, drains a watershed of approximately 236 square miles in the Sierra Nevada. Because of the relatively low elevation of the watershed, most of the flow in the Chowchilla River results from rainfall. Historically, the Chowchilla River has behaved as an ephemeral stream with large winter flood flows and near zero summertime flows. The Chowchilla River ultimately discharges into the East Side Bypass.

The only regulating reservoir on the Chowchilla River is Eastman Lake (formed by Buchanan Dam), which was completed and operational in 1976 and has a maximum storage capacity of 150,600 acre-feet per year. Buchanan Dam is operated by the COE, and releases are coordinated with Reclamation operations at Friant Dam. Generally, direct diversions from the Chowchilla River are supplemented by supplies from the Madera Canal. Releases from Buchanan Dam help meet the supplemental water demand and reduce the need for water from the Madera Canal. During flood control operations, Madera Canal spills can be released down Ash and Berenda sloughs, approximately 10 miles downstream of Buchanan Dam.

LOWER SAN JOAQUIN RIVER AND TRIBUTARIES

The lower San Joaquin River comprises the section of river from the confluence with the Merced River (below Fremont Ford) to Vernalis, which is generally considered to represent the southern limit of the Delta. The drainage area of the San Joaquin River above Vernalis includes approximately 13,356 square miles, of which approximately 2,100 square miles are drained by Fresno Slough (James Bypass). As described in the previous section, little water is contributed from the upper San Joaquin River, except during flood events. Flow patterns are therefore primarily governed by the tributary inflows from the Merced, Tuolumne, and Stanislaus rivers.

Merced River

The Merced River originates in the Sierra Nevada, and drains an area of approximately 1,273 square miles east of the San Joaquin River. Portions of the upper Merced watershed drain national park lands. The average unimpaired runoff in the basin is approximately 1 million acre-feet per year. The median historical unimpaired runoff is 0.8 million acre-feet per year, with a range of 0.2 to 2.8 million acre-feet per year.

Agricultural development in the Merced River watershed began in the 1850s, and significant changes have been made to the hydrologic system since that time. The enlarged New Exchequer Dam, forming Lake McClure with a capacity of 1,024,000 acre-feet per year, was completed in 1967 and now regulates releases to the lower Merced River. New Exchequer Dam is owned and operated by the Merced Irrigation District for power production, irrigation, and flood control.

Releases from Lake McClure pass through a series of powerplants and smaller diversions and are re-regulated at McSwain Reservoir, which serves as an afterbay to New Exchequer Dam. Below McSwain Dam, water is diverted to Merced Irrigation District's Northside Canal at the PG&E Merced Falls Dam for delivery to 4,100 acres of land within the district (USGS, 1992). The Crocker Huffman Dam, Merced ID's main diversion point located downstream of the Merced Falls Dam near the town of Snelling, diverts water into the Main Canal.

Tuolumne River

The Tuolumne River originates in the Sierra Nevada, and drains a watershed of approximately 1,540 square miles. The Tuolumne River is the largest tributary to the San Joaquin River with an annual average unimpaired runoff of approximately 1.95 million acre-feet per year. The median historical unimpaired runoff is 1.8 million acre-feet per year, with a range of 0.4 to 4.6 million acre-feet per year.

Flows in the lower portion of the Tuolumne River are controlled primarily by the operation of New Don Pedro Dam, which was constructed in 1971 jointly by TID and MID with participation by the City and County of San Francisco. The 2.0-million-acre-foot reservoir stores water for agricultural irrigation, hydroelectric generation, fish and wildlife enhancement, recreation, and flood control purposes. The districts divert water to the Modesto Main Canal and the Turlock Main Canal a short distance downstream from New Don Pedro Dam at La Grange Dam.

The City and County of San Francisco operates several water supply and hydroelectric facilities within the Tuolumne River Basin upstream of New Don Pedro Reservoir. O'Shaughnessy Dam on the main stem of the Tuolumne River, completed in 1923, impounds approximately 0.4 million acre-feet per year of water in Hetch Hetchy Reservoir. The 460-square-mile drainage area is entirely within the boundaries of Yosemite National Park. Water from Hetch Hetchy is used primarily to meet the M&I water needs of the City and County of San Francisco and to provide instream flows in the Tuolumne River below O'Shaughnessy Dam. Two other storage facilities upstream of Hetch Hetchy Reservoir, Lake Eleanor and Cherry Lake, are operated for hydropower and water supply purposes. The combined capacity of these two reservoirs is about 0.4 million acre-feet per year. The City and County of San Francisco owns 0.6 million acre-feet per year of storage in New Don Pedro Reservoir, which allows them to meet part of their release obligations to the districts by exchanging stored water for water diverted upstream at Hetch Hetchy.

Stanislaus River

The Stanislaus River originates in the Sierra Nevada and drains a watershed of approximately 900 square miles. The average unimpaired runoff in the basin is approximately 1.2 million acre-feet per year; the median historical unimpaired runoff is 1.1 million acre-feet per year, with a range of 0.2 to 3.0 million acre-feet per year. Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of May and June.

Agricultural water supply development in the Stanislaus River watershed began in the 1850s, and has significantly altered the basin's hydrologic conditions. Currently, the flow in the lower Stanislaus River is primarily controlled by New Melones Reservoir, which was completed by the COE in 1978 and approved for filling in 1983 with a storage capacity of about 2.4 million acre-feet per year. New Melones Reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River and is operated by Reclamation as part of the CVP. It is operated primarily for purposes of water supply, flood control, power generation, fishery enhancement, water quality improvement, and recreation. Flood control operations are conducted in conformance with COE operational guidelines.

Other water storage facilities in the Stanislaus River watershed include the Tri-Dam Project, a hydroelectric generation project that consists of Donnells and Beardsley dams located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and Powerplant approximately 6 miles downstream of New Melones Dam on the mainstem Stanislaus River. Releases from Donnells and Beardsley dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation and the OID and SSJID, Tulloch Reservoir provides afterbay storage to re-regulate power releases from New Melones Powerplant.

The main water diversion point on the Stanislaus is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam. Goodwin Dam, which was constructed by OID and SSJID in 1912, creates a re-regulating reservoir for releases from Tulloch Powerplant and provides for diversions to canals north and south of the Stanislaus River for delivery to OID and SSJID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to Central San Joaquin Water Conservation District and the Stockton East Water District.

Twenty ungaged tributaries contribute flow to the lower portion of the Stanislaus River, below Goodwin Dam. These streams provide intermittent flows, occurring primarily during the months of November through August. Agricultural return flows as well as spills from irrigation canals receiving water from both the Stanislaus and Tuolumne rivers enter the lower portion of the Stanislaus River. In addition a portion of the flow in the lower portion of the Stanislaus River originates from groundwater accretions. As a result of these additional sources, annual streamflows measured at Ripon, approximately 35 miles downstream of Goodwin Dam, are nearly 30 percent larger than those measured below Goodwin Dam.

The original Melones Dam was constructed in 1924 and was operated in coordination with upstream storage facilities and Goodwin Dam downstream. Diversions at Goodwin Dam predate available flow data in this portion of the Stanislaus River. Figure II-10 shows the distribution of annual flows in the Stanislaus River below Goodwin from 1958 to 1992. Prior to the construction of New Melones Dam, average monthly flows were generally uniform between January and June, with peak flows in May. As a result of limited storage capacity in facilities on the river, average monthly flows in August and September approached zero in many years. The construction of New Melones Dam enhanced flood control and storage capacity on the Stanislaus River considerably. Following construction of New Melones Dam, average monthly flows included peak flows in March, with releases in all months. In 1992, in the later portion of an extended drought, storage in New Melones dropped to approximately 80,000 acre-feet per year.

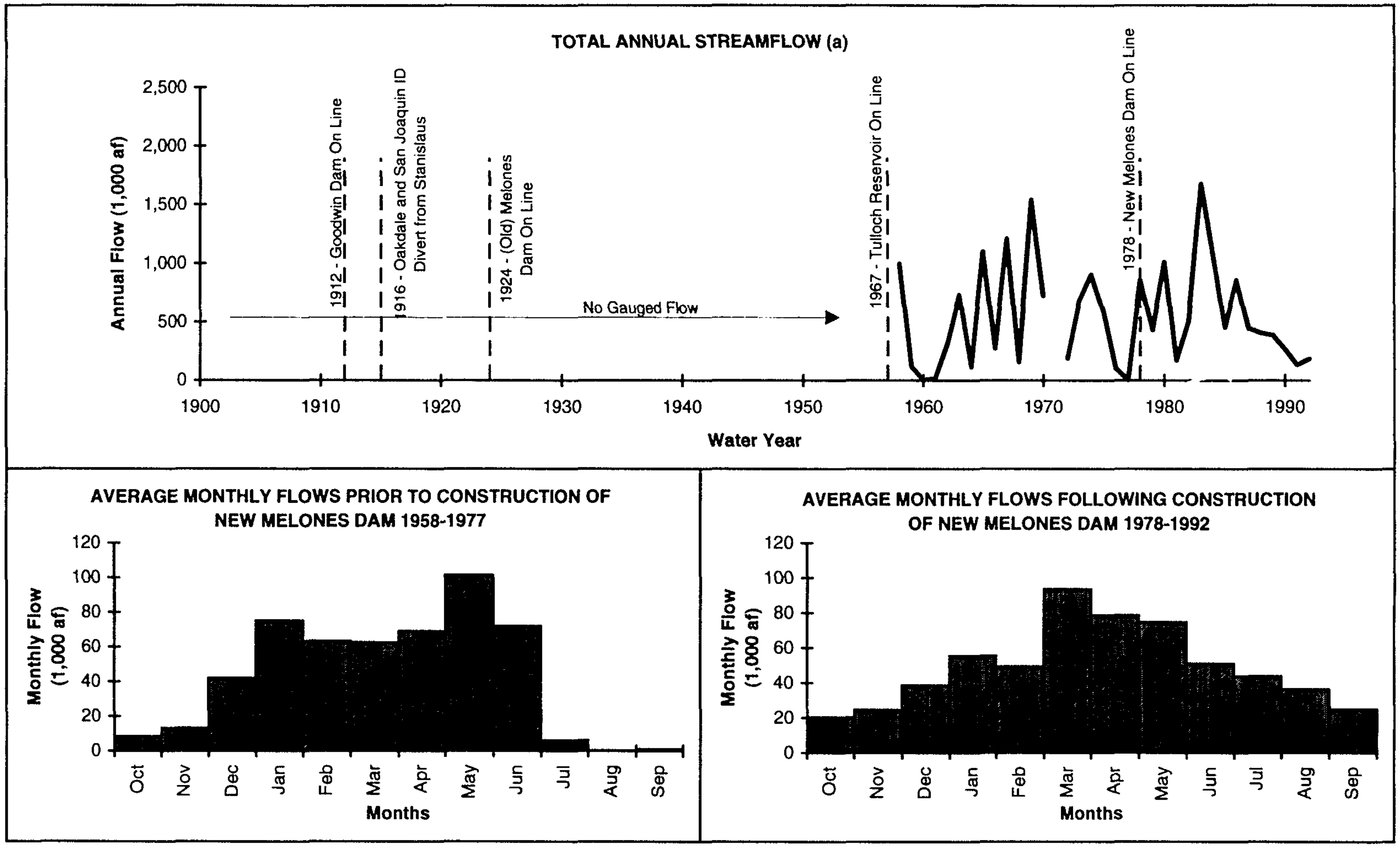
Operations of New Melones Reservoir are affected by water rights obligations, instream fishery requirements, water quality objectives in the Stanislaus and San Joaquin rivers, and CVP contracts. A description of operational criteria for New Melones Reservoir is provided with a discussion of CVP operations in a later section of this chapter.

San Joaquin River at Vernalis

Flows in the San Joaquin River at Vernalis are affected by the operation of upstream facilities on the San Joaquin, Merced, Tuolumne, and Stanislaus rivers, as well as by deliveries to the Mendota Pool from the Delta-Mendota Canal, and overflows from the Kings River in the Tulare Lake Region. Figure II-11 shows the annual flows at this location between 1930 and 1992. Changes in flows at Vernalis are consistent with changes in flows in the upper San Joaquin, Merced, Tuolumne, and Stanislaus rivers. In general, average monthly flows prior to 1940 included peak flows during the months of May and June, which correspond to the largest snowmelt flows in the San Joaquin River Basin. Following 1940, the flow in the San Joaquin River Basin was affected by the construction of Friant, New Exchequer, New Don Pedro, and New Melones dams. Construction of these facilities occurred between 1941 and 1978. Their effect is evident in a plot of average monthly flows from 1978 to 1992. Average monthly flows in the San Joaquin River at Vernalis during this period are more uniform throughout the year, with maximum flows less than historical levels.

Calaveras River

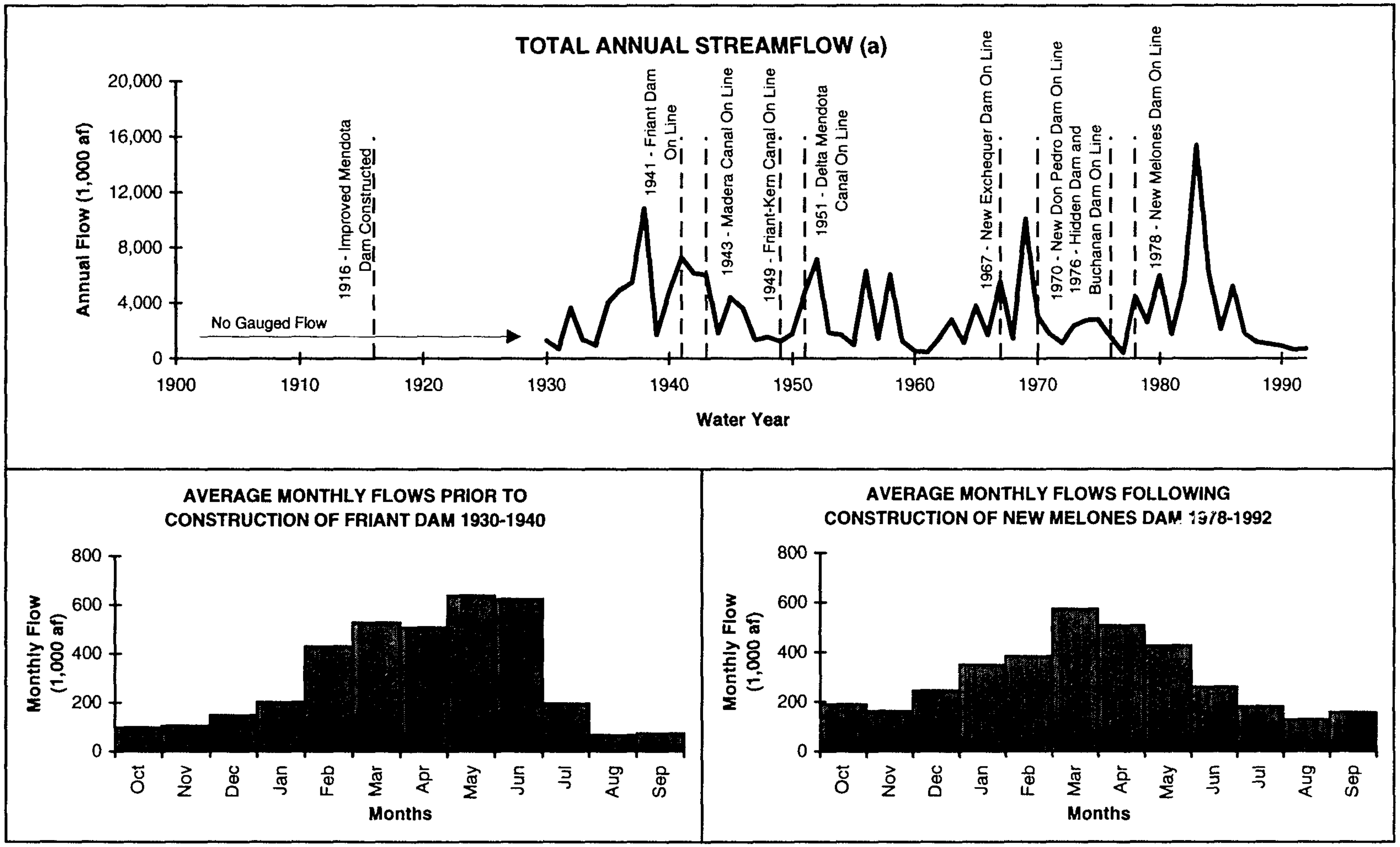
The Calaveras River originates in the Sierra Nevada, drains an area of approximately 363 square miles, and enters the San Joaquin River near the City of Stockton. The Calaveras River watershed is almost entirely below the effective average snowfall level (5,000 feet), and receives nearly all of its flow from rainfall. As a result, nearly all of the annual flow occurs between November and April. The median historical unimpaired runoff is 130,000 acre-feet per year, with a range of 8,000 to 600,000 acre-feet per year. Seepage from the north fork of the Stanislaus River also enters the basin from diversion canals and reservoirs. The portion of the river in the valley is commonly subject to periods of low or no flow for many days or weeks in the late summer and early fall.



NOTE: (a) First full year of stream flow data available in 1958. No data were recorded for WY 1971.
Flow regulated by Tulloch Reservoir since 1957, and by New Melones Dam since 1978.

FIGURE II-10

HISTORICAL STREAMFLOW IN THE STANISLAUS RIVER BELOW GOODWIN DAM



NOTE: (a) First full year of stream flow data available in 1924. Data for the period from 1924 to 1929 are not shown because only low-flow records are available for that period. Pre-1900 development on the San Joaquin River: 1869-Main and Outside canals constructed; 1871-Mendota Dam (Weir) constructed; 1872-Miller-Lux Canal constructed. USGS Station 11303500 is a National Stream Quality Accounting Network Station.

FIGURE II-11

HISTORICAL STREAMFLOW IN THE SAN JOAQUIN RIVER NEAR VERNALIS

The major water management facility on the Calaveras River is New Hogan Dam and Lake. It was constructed in 1963 by the COE and is operated by the COE and Stockton East Water District. New Hogan Lake has a storage capacity of 317,000 acre-feet per year. New Hogan Dam is operated primarily for flood control purposes, with the specification that flows at Bellota remain below 6,000 cfs.

Mokelumne River

The Mokelumne River originates at an elevation of approximately 10,000 feet in the Sierra Nevada and drains a watershed of approximately 661 square miles. It is a major tributary to the Delta, entering the lower San Joaquin River northwest of Stockton. The median historical unimpaired run-off is 696,000 acre-feet per year, with a range of 129,000 to 1.8 million acre-feet per year.

Three major reservoirs influence streamflow in the Mokelumne River. The uppermost reservoir, Salt Springs Reservoir, is owned by PG&E and is located on the North Fork of the Mokelumne River. It has a storage capacity of 141,900 acre-feet per year and began operation in 1963. Pardee and Camanche reservoirs are located on the main stem of the Mokelumne and are both owned and operated by the EBMUD. Pardee, completed in 1929, has storage capacity of 209,900 acre-feet per year. Water is exported from the Mokelumne River watershed to the EBMUD service area via the Mokelumne River Aqueduct, which receives water directly from Pardee Reservoir. Camanche Reservoir, with a storage capacity of 430,800 acre-feet per year, is located downstream of Pardee Dam. Water is released from Camanche Reservoir to maintain downstream water requirements and to provide flood protection on the Mokelumne River.

Approximately 82 diversions were identified along the Mokelumne River (DWR Bulletin 130-68). Except for the Mokelumne Aqueduct diversion, the most significant diversion in the watershed occurs at Woodbridge Dam, which diverts water into the Woodbridge Canal for irrigation of land south and west of the Town of Woodbridge.

Cosumnes River

The Cosumnes River originates in the lower elevations of the Sierra Nevada, drains a watershed of approximately 537 square miles, and enters the Mokelumne River within the Delta near the Town of Thornton. Because of the low elevation of its headwaters, the Cosumnes River receives most of its water from rainfall.

The only major water supply facilities in the Cosumnes River watershed are components of the Sly Park Unit of the CVP. The Sly Park Unit includes Jenkinson Lake, formed by Sly Park Dam on Sly Park Creek, with a storage capacity of 41,000 acre-feet per year. Water is diverted from the lake into the Camino Conduit for delivery to the El Dorado Irrigation District (EID) for irrigation and municipal uses by the City of Placerville and neighboring communities. A small diversion dam on Camp Creek diverts water through the Camp Creek Tunnel into Jenkinson Lake. These facilities were originally constructed as part of the CVP, and upon completion, operations were transferred to the EID under contract with Reclamation. The water supply provided by the Sly Park Unit is used by EID and is not integrated into the CVP operations.

SURFACE WATER QUALITY IN THE SAN JOAQUIN RIVER BASIN

Surface water quality in the San Joaquin River Basin is affected by several factors, including natural runoff, agricultural return flows, biostimulation, construction, logging, grazing, operations of flow regulating facilities, urbanization, and recreation. In addition, irrigated crops grown in the western portion of the San Joaquin Valley have accelerated the leaching of minerals from soils, which has altered water quality conditions in the San Joaquin River system.

The upper reaches of the rivers draining to the San Joaquin River Basin originate in large drainage areas high on the west side of the Sierra Nevada. The water in these rivers is generally soft with low mineral concentrations. As these streams flow from the Sierra Nevada foothills across the eastern valley floor, their mineral concentration steadily increases. This increase in concentration is fairly uniform for each of the east side streams.

In the western part of the San Joaquin Valley, soils are derived mainly from the marine sediments that make up the Coast Range and are high in salts and trace elements such as selenium, molybdenum, arsenic, and boron. As the San Joaquin Valley has undergone extensive land development, erosion and drainage patterns have been altered, thereby accelerating the rate at which these trace elements have been dissolved from the soil to accumulate in shallow groundwater, streams, and the San Joaquin River. The term "shallow groundwater" refers to as the highest zone of saturation down to a depth of approximately 20 feet below ground surface.

The primary area of subsurface drainage problems extend along the western side of the San Joaquin Valley from the Delta to south of Bakersfield. Shallow semi-impermeable clay layers lie beneath the land surface, preventing adequate drainage of irrigation water. This impediment to downward flow has resulted in high groundwater levels in the shallow groundwater zone and requires subsurface drainage of low lying fields to prevent waterlogging and salt buildup in the root zone. The subsurface drainage water is characterized by high salt concentrations and elevated levels of trace elements.

Wildlife refuges and duck clubs also contribute water of degraded quality to the San Joaquin River. The refuges begin flooding operations in the fall to maintain habitat for migratory waterfowl, primarily with water delivered from the Delta via the Delta-Mendota Canal. The salinity of the water in the ponds may increase during the fall due to evaporation and following winter seasons with low precipitation, often contributing poor quality water to the San Joaquin River when the ponds are drained in the spring.

Water quality in the San Joaquin River varies considerably along the stream's length. Above Millerton Lake and downstream towards Mendota Pool, water quality is generally excellent. The reach from Gravelly Ford to Mendota Pool (about 17 miles) is frequently dry except during flood control releases because all water released from Millerton Lake is diverted upstream to satisfy water rights agreements, or percolates to groundwater. During the irrigation season, most of the water released from the Mendota Pool to the San Joaquin River is imported from the Delta via the Delta-Mendota Canal, and generally has higher concentrations of total dissolved solids (TDS) than water in the upper reaches of the San Joaquin River. Most of the water released from the Mendota Pool to the San Joaquin River is diverted at or above Sack Dam for agricultural uses.

Between Sack Dam and the confluence with Salt Slough, the San Joaquin River is often dry. From Salt Slough to Fremont Ford, most of the flow in the San Joaquin River is derived from irrigation returns carried by Salt and Mud sloughs. This reach typically has the poorest water quality of any reach of the river.

As the San Joaquin River progresses downstream from Fremont Ford, water quality generally improves at successive confluences, specifically at those with the Merced, Tuolumne, and Stanislaus rivers. In the relatively long reach between the Merced and Tuolumne rivers, however, mineral concentrations tend to increase due to agricultural drainage water, other waste waters, and effluent groundwater (DWR, 1965). Total dissolved solids in the San Joaquin River near Vernalis have historically ranged from 52 mg/l (at high stages) to 1,220 mg/l during the 1951-1962 period (DWR, 1965). During the mid to late 1960s, San Joaquin River water quality continued to decline. In 1972, the SWRCB) included a provision in Decision 1422 (D-1422) that Reclamation maintain average monthly concentrations of TDS in the San Joaquin River at Vernalis of 500 mg/l, as a condition of the operating permit for New Melones Reservoir on the Stanislaus River.

SURFACE WATER IN THE SACRAMENTO-SAN JOAQUIN DELTA

The Delta, Figure II-12, lies at the confluence of the Sacramento and San Joaquin rivers. It occupies the area of lowest elevation in the Central Valley, extending from the confluence of the two rivers inland as far as Sacramento and Stockton. In its original state, the Delta area included swamp and overflow lands comprising some of the most fertile peat soils in the state.

Prior to the settlement of Europeans in California, the Delta had evolved geologically and hydrologically with a network of slow-moving river channels dependent on and influenced by the confluence of the Sacramento and San Joaquin rivers, and to a lesser extent on the Mokelumne, Calaveras, and Cosumnes rivers (State Lands Commission, 1991). Cyclic river flooding helped contribute material along the stream channels forming natural levees. These levees formed around islands creating environments for tule marsh.

Much of the land within the Delta was reclaimed between 1850 and 1930 through the construction of levees around the numerous islands. This construction resulted in the creation of a network of navigable river channels, sloughs, and dredger cuts. During the 1850s through 1880s, extensive hydraulic gold mining contributed sediment loads to the major northern California rivers, which consequently carried this material into the Delta. The increased sedimentation in the Delta caused extensive flooding and led to the construction of levees at greater heights to reduce flooding. By 1900, approximately 50 percent of Delta lands had been reclaimed. By 1930, essentially all Delta islands had been reclaimed. These transformations were followed by the construction of major water diversions for agricultural and urban water needs. Currently, the Delta includes 57 major reclaimed islands and nearly 800 unleveed islands, and encompasses approximately 1,153 square miles. Much of the land in the Delta lies below sea level.

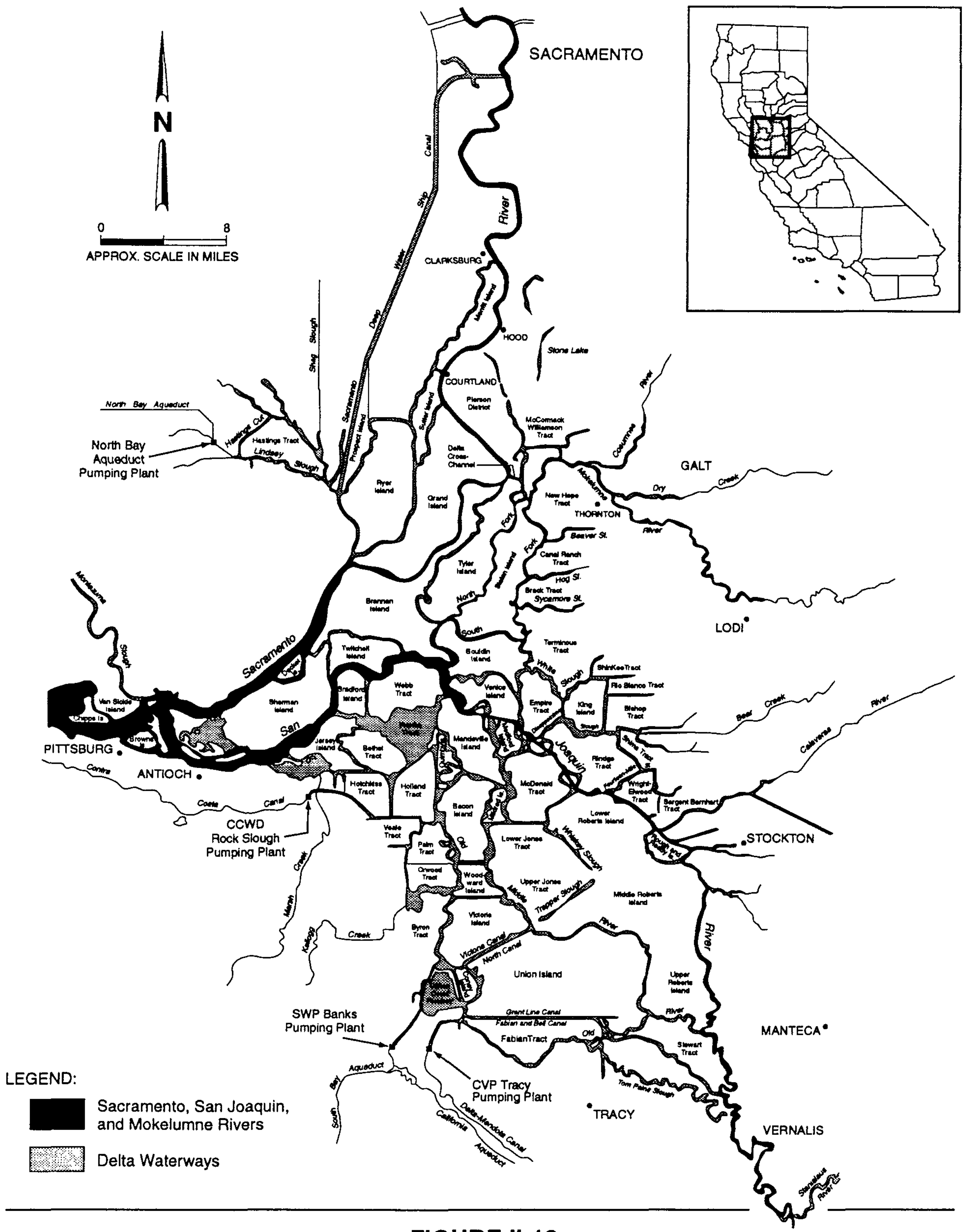


FIGURE II-12

SACRAMENTO-SAN JOAQUIN DELTA

On the average, about 21 million acre-feet per year of water, or about 42 percent of the surface water in California, reaches the Delta. Actual flow varies widely from year to year, and within the year as well. In 1977, a year of extraordinary drought, inflow to the Delta totaled 5.9 million acre-feet per year. In 1983, an extremely wet year, annual inflow was about 70 million acre-feet per year. Approximately 50,000 acres of the Delta is covered by surface water, and approximately 520,000 acres of Delta land is used for agriculture.

Delta channels have been modified to allow transport of this water and to reduce the effects of pumping on the direction of flows and salinity intrusion. The conveyance of water from the Sacramento River southward through the Delta is aided by the Delta Cross Channel (DCC), a man-made gated channel that conveys water from the Sacramento River to the Mokelumne River. Water diversions in the Delta include the CVP Tracy Pumping Plant, the State Water Project Banks Pumping Plant, the Contra Costa Canal Pumping Plant, the North Bay Aqueduct, and over 1,800 agricultural diversions for in-Delta use.

The hydraulic characteristics of the Delta are influenced by inflows from tributary streams, tidal influence from the Pacific Ocean, and water diversions within the Delta. Accordingly, water quality in the Delta is highly variable. It is strongly influenced by inflows from the rivers, as well as by intrusions of seawater into the western and central portions of the Delta during periods of low outflow that may be affected by high export pumping. The concentrations of salts and other materials in the Delta are affected by river inflows, tidal flows, agricultural diversions, drainage flows, wastewater discharges, water exports, cooling water intakes and discharges, and groundwater accretions.

Seawater intrusion into the Delta is dependent on tidal conditions, inflows to the Delta, and Delta channel geometry. Delta channels are typically less than 30 feet deep, unless dredged, and vary in width from less than 100 feet to more than 1 mile. Although some channels are edged with riparian and aquatic vegetation, steep mud or rip-rap covered levees border most channels. To enhance flow and aid in levee maintenance, vegetation is often removed from the channel margins. The tidal currents carry large volumes of seawater back and forth through the San Francisco Bay-Delta Estuary with the tide cycle. The mixing zone of salt and fresh water can shift 2 to 6 miles daily depending on the tides, and may reach far into the Delta during periods of low inflow.

Major CVP facilities in the Delta include the Tracy Pumping Plant, completed in 1951, which pumps water from Old River to the Delta-Mendota Canal; the Contra Costa Pumping Plant, which pumps water from Rock Slough into the Contra Costa Canal; and the DCC, which was completed in 1951 and permits the diversion of water from the Sacramento River to the Mokelumne River, facilitating efficient transfer of water across the Delta to project pumps in the southern Delta. The SWP also operates and maintains facilities in the Delta. These include the Barker Slough Pumping Plant in the north Delta, which pumps water into the North Bay Aqueduct and the Harvey O. Banks Delta Pumping Plant, which pumps water from Clifton Court Forebay in the southern Delta into the California Aqueduct.

Currently, salinity problems occur primarily during years of below normal runoff. In the western Delta, elevated salinity levels result primarily from the intrusion of saline waters from the San Francisco Bay system. Salinity concentrations in the southern portion of the Delta results partially from elevated concentrations of salts in the San Joaquin River as it flows into the Delta. The operations of the state and federal export pumping plants near Tracy draw higher quality Sacramento River water southward across the Delta. These conditions result in higher salinity concentrations in the southeast portion of the Delta. Localized problems resulting from irrigation returns occur elsewhere such as in dead-end sloughs.

SURFACE WATER IN THE TULARE LAKE BASIN

The Tulare Lake Region is defined generally by the Tulare Lake Basin, which is hydrologically separate from the San Joaquin River Basin, except under certain hydrologic and operational conditions where water from the Kings River overflows into the San Joaquin River. As shown in Figure II-13, four major rivers drain the Tulare Lake Basin: the Kings, Kaweah, Tule, and Kern. The three northern rivers (Kings, Kaweah, and Tule) historically drained to the Tulare Lake Bed, a vast lowland area that covers approximately 200,000 acres in Kern and Kings counties. The Kern River historically flowed into the Kern, Buena Vista, and Goose lake beds. The development and operation of flood control and water supply projects on these rivers has significantly reduced flow to the lake beds, which now remain dry except during periods of high flows in wet years. The lake beds are connected through a series of sloughs that allow transport of overflows during wet weather. Kern Lake empties into Buena Vista Lake and Tulare Lake. In addition, the north fork of the Kings River overflows into the San Joaquin River, via the Fresno Slough. Under most condition, streams in the Tulare Lake Basin are not tributary to the Delta and do not support anadromous fisheries.

KINGS RIVER

The Kings River originates in the southern Sierra Nevada. The upper watershed includes the North, Middle, and South forks of the Kings River, all of which converge in the foothills above Pine Flat Reservoir. Downstream of the reservoir, the river bifurcates at Crescent Wier into the South Fork, which flows into Tulare Lake, and the North Fork/Fresno Slough, which flows north into Mendota Pool. The Kings River drainage area above Pine Flat Dam covers approximately 1,545 square miles.

The main flow-regulating facility on the Kings River is Pine Flat Dam, which was completed by the COE in 1954. The reservoir is used for flood control and conservation storage and has a usable storage capacity of 1 million acre-feet per year. Four reservoirs upstream of Pine Flat Dam supply water to hydropower projects on the North Fork. Below Pine Flat Dam, the Friant-Kern Canal crosses the Kings River. There are 14 diversions located on the mainstem of the river between Pine Flat Dam and Crescent Weir, one agricultural diversion on the North Fork/Fresno Slough, and eight diversions on the South Fork.

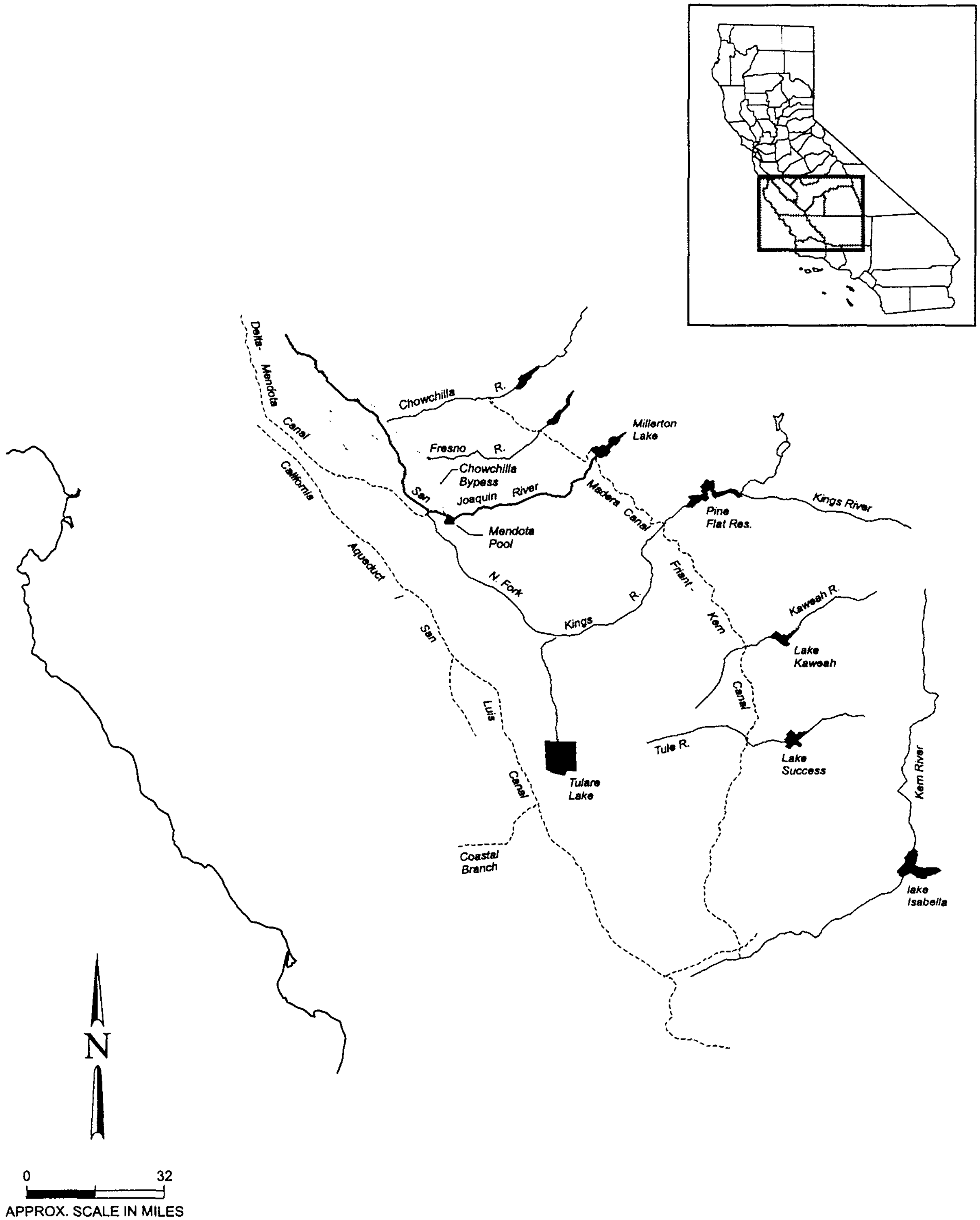


FIGURE II-13

TULARE LAKE BASIN

KAWEAH RIVER

The headwaters of the Kaweah River lie in the southern Sierra Nevada. The upper watershed includes the North, Marble, Middle, East, and South forks of the Kaweah River, all of which converge in the foothills above Lake Kaweah. Downstream of the lake the main stem of the Kaweah meanders southwest past Visalia and on to the valley floor. The Kaweah River drainage area above Terminus Dam extends over approximately 561 square miles.

The main regulating facility on the Kaweah River is Terminus Dam, completed by the COE in 1962. The lake is used for flood control and water supply and has a usable storage capacity of 149,600 acre-feet per year. Three hydropower diversions above Lake Kaweah return all of the diverted water to the river. Approximately 12 diversions below Lake Kaweah supply water for agricultural purposes.

TULE RIVER

The Tule River originates in the southern Sierra Nevada. The upper watershed includes the North, Middle, and South forks of the Tule River, which converge in the foothills above Lake Success. Downstream of the lake the main stem of the Tule meanders west through Porterville and across the valley floor until it drains into Tulare Lake, which is generally dry. The Tule River drainage area above Success Dam covers approximately 393 square miles.

The main regulating facility on the Tule River is Success Dam, completed by the COE in 1961. The reservoir is used for flood control and water supply and has usable storage capacity of 82,000 acre-feet per year plus an additional 120,000 acre-feet per year of surcharge flood control storage. Above Lake Success, two hydropower diversions return most of the diverted water to the river. Some water for agricultural purposes is diverted from one of the hydropower projects after passing through the powerhouse. There are other small agricultural diversions above the lake. Between Lake Success and Tulare Lake are eight notable agricultural diversions that averaged from 500 to 21,400 acre-feet per year from 1961 to 1977.

KERN RIVER

The headwaters of the Kern River are located high in the Sierra Nevada. The upper watershed includes the South Fork of the Kern River and the main stem of the Kern River. The main stem flows south through the mountains and directly into Isabella Lake. Below the lake, the river flows southwest towards Bakersfield, where it enters the valley floor and continues to the Buena Vista lake bed. The Kern River drains approximately 2,074 square miles above Isabella Lake.

The main regulating facility on the Kern River is Isabella Dam, completed by the COE in 1953. The reservoir created by Isabella Dam has a capacity of 570,000 acre-feet per year. West of Bakersfield, the Friant-Kern Canal terminates at the Kern River. From 1961 to 1977, the Friant-Kern Canal delivered about 18,000 acre-feet per year of water per year to the river. Above Isabella Lake are one hydropower diversion and two agricultural diversions. Three more hydropower diversions are located downstream of the lake. All the hydropower diversions on the Kern River return the water to the river. There are 14 agricultural diversions from the Kern

River. From 1961 to 1977 the total annual diversion from all 14 ranged from 175,000 to 2 million acre-feet per year and averaged 427,000 acre-feet per year.

SURFACE WATER QUALITY IN THE TULARE LAKE REGION

In general, the Tulare Lake Region has not had major surface water quality problems. The perennial streams (Kings, Kaweah, Tule, and Kern rivers) are not directly subject to significant man-made waste loads because most effluents are applied to the land. Irrigation return water flows do contribute a major portion of the summer base flow in the lower reaches of the larger streams. In addition, saline water from oil wells contributes to upper reaches of the Kern River, increasing the basin salt load.

Evaporation ponds are used for disposal of drainage water in the Tulare Lake Region. The waters in the ponds are typically brackish, so they are not used for any beneficial purposes. However, waterfowl frequently use these ponds. Fish and wildlife agencies periodically monitor levels of trace elements in the vegetation and the wildlife that use the ponds. High selenium concentrations pose a particular threat to waterfowl breeding and feeding in these waters.

Streams in the Tulare Lake Region are similar to streams in the San Joaquin River Region in that water quality is generally excellent upstream of the valley floor and the surface water supply reservoirs in the foothills. Water of the four main streams in the Tulare Lake Region is generally calcium carbonate in character. The headwaters of these streams are generally characterized by higher TDS levels than streams that flow into the San Joaquin River Region.

Surface waters in the Tulare, Buena Vista, and Kern lake beds are strongly affected by drainage water flows. These water bodies tend to have extremely high levels of TDS, selenium, boron, arsenic, and molybdenum.

THE CENTRAL VALLEY PROJECT OPERATIONS

The CVP is the largest surface water storage and delivery system in California, with a geographic scope covering 35 of the state's 58 counties. The project includes 20 reservoirs, with a combined storage capacity of approximately 11 million acre feet; 8 powerplants and 2 pumping-generating plants, with a combined capacity of approximately 2 million kilowatts; 2 pumping plants; and approximately 500 miles of major canals and aqueducts. The CVP supplies water to more than 250 long-term water contractors in the Central Valley, and Santa Clara Valley and the San Francisco Bay Area. Figure II-14 shows the locations of CVP facilities, rivers that are controlled or affected by the operation of CVP facilities, and the CVP service area.

Historically, approximately 90 percent of the CVP water has been delivered to agricultural users, including prior water rights holders. Total annual contracts exceed 9 million acre-feet per year, including over 1 million acre-feet per year of Friant Division Class II supply, which is generally available only in wet years. At present, increasing quantities of water is being provided to municipal customers, including the cities of Redding, Sacramento, Folsom, Tracy, and Fresno; most of Santa Clara County; and the northeastern portion of Contra Costa County.

As discussed previously in this chapter, the CVP was authorized through a series of legislative actions, beginning with the Rivers and Harbors Act of 1935 (Act), which authorized construction of initial features of the CVP. Additional facilities, which increased the storage and delivery capacity of the CVP, were authorized in successive congressional acts. In general, facilities were authorized for construction and operation as divisions or units, which are components of divisions. The CVP facilities include reservoirs on or near the Trinity, Sacramento, American, Stanislaus, and the San Joaquin rivers, as shown in Figure I-1.

Water from the Trinity River is stored, reregulated, and diverted through a system of dams, reservoirs, tunnels, and powerplants in the Sacramento River for use in water deficient areas of the Central Valley Basin. Water is also conveyed in the Sacramento River to and through the Delta to the Tracy Pumping Plant at the southern end of the Delta. The Tracy Pumping Plant lifts the water into the Delta-Mendota Canal which delivers water to CVP contractors and exchange contractors on the San Joaquin River and other water right contractors on the Mendota Pool. CVP water may continue to be conveyed via the San Luis Reservoir and Pacheco Tunnel to the San Felipe Division contractors and via the San Luis Canal to San Luis contractors.

The CVP also delivers water from the San Joaquin River to CVP contractors and water right holders located near the Madera and Friant Kern canals. Water from New Melones Reservoir is used by water rights holders in the Stanislaus River watershed and CVP contractors located in the northern San Joaquin Valley. Some of the CVP Contractors divert directly from or just below the outlet works from Whiskeytown, Folsom, and Millerton Reservoirs. In addition, water is conveyed via the Sacramento and American rivers to CVP contractors, water rights holders along the Sacramento and American rivers.

Other CVP smaller reservoir and rivers that are financially integrated in the CVP include the Hidden and Buchanan reservoirs on the Fresno and Chowchilla rivers respectively; the Sly Park Reservoir and the Consumnes River; Black Butte Reservoir on the Stony Creek.

This section summarizes the operations of the CVP, beginning with a description of factors that influence operations decisions. It includes a summary of project-wide decision criteria used to determine when and where water should be stored or released. This is followed by descriptions of operating constraints and objectives for specific facilities in CVP divisions. The section concludes with a discussion of CVP contract types and criteria used to determine annual water delivery levels to the various types of contractors.

GENERAL CRITERIA FOR THE OPERATION OF CVP FACILITIES

Decisions related to the operation of the CVP must consider a wide variety of project-wide, regional, and site-specific factors. In the development of operations decisions, criteria related to reservoir operations, downstream conditions, and water rights in the Delta must be considered. This section describes how these issues generally influence CVP operational decisions.

FIGURE II-14

CENTRAL VALLEY PROJECT AND OTHER RELATED FEDERAL FACILITIES

Regulatory requirements that affect operations, and operational considerations at specific facilities are described in later sections of this chapter.

Reservoir Operating Criteria

Factors that influence the operation of CVP reservoirs include inflow, release requirements, flood control requirements, carryover storage objectives, lake recreation, power production capabilities, cold water reserves, and pumping costs. Operational decisions must consider conditions at an individual reservoirs, as well as conditions at other project reservoirs. The possibility of using multiple water sources to meet some requirements provides flexibility to project operations and adds complexity to operational decisions. For example, storage space south of the Delta that can only be filled with water exported from the Delta is a major operational consideration involving the geographic distribution of water in storage.

The COE is responsible for determining flood control operational requirements at most CVP reservoirs. If CVP reservoir storage exceeds COE requirements, water must be released at rates of flow defined in the COE's flood control manuals. These manuals require lower reservoir storage levels in the fall in anticipation of winter rains. To avoid excess releases at the end of the summer, Reclamation often schedules releases in excess of minimum flow requirements over the course of the summer. This practice generally results in end of water year reservoir storage levels at or below flood control thresholds so that space is available to regulate reservoir inflows.

Because future hydrologic conditions are difficult to predict for the coming water year, CVP operators must anticipate conditions ranging from drought to flood. Reservoirs are operated with consideration for some degree of protection for future supplies in the event of dry conditions. Carryover storage at the end of September forms an initial basis for the following year's operating conditions and is an integral part of the process of allocating CVP water supplies. Carryover objectives consider flood protection or Safety of Dams criteria, existing water demands, forecasted water supply, cold water supplies, power system requirements, risk of drought conditions, possible impacts beyond the end of the current water year, and other operational factors.

As a water year progresses, carryover storage projections help guide CVP operations. During the fall months, carryover storage is the only indicator of CVP capabilities, until winter precipitation or lack of winter precipitation can be assessed. By April or May, when the wet season is essentially over, CVP operational objectives are generally known and CVP storage may be used as necessary to efficiently meet these objectives. Carryover storage may be affected by contingencies affecting CVP operations, unusual hydrologic events, and variations from forecasted inflows. During the summer, if carryover storage is expected to be less than next season's maximum allowed flood control Safety of Dams criteria, releases may be shifted among project reservoirs to achieve the desirable carryover objective at individual reservoirs, given all the CVP's operational objectives.

Water temperatures in CVP reservoirs vary by geographic location, time of the year, depth of water, and temperature stratification characteristics of the reservoirs. Water temperatures in high-altitude reservoirs are typically lower than at reservoirs at low altitudes and are less affected by the warming of the ambient air. Also, reservoirs with a relatively low surface area per unit volume experience less warming than reservoirs with a larger surface in relation to volume.

Temperature stratification is more common in large reservoirs than in smaller reservoirs and occurs when deep water is cooler than water at or near the surface. Stratification most commonly occurs in the summer and fall and is generally absent in winter and spring. This presents a challenge to operations, when cool water is needed for releases during the summer and fall for downstream fisheries. CVP operators attempt to preserve cold water pools in Clair Engle, Shasta, and Folsom reservoirs for the benefit of salmon and steelhead in the Trinity, Sacramento, and American rivers.

Full, or nearly full, reservoirs provide optimal recreation opportunities. CVP operations staff attempt to achieve reservoir levels that maintain good recreation opportunities through the prime recreation season (Memorial Day through Labor Day).

To maximize the opportunity for power production, storage levels should be at the highest levels allowable to increase hydraulic head, and releases should not exceed the capacities of CVP powerplants. As described above, CVP operators often release water during the summer to avoid large releases at the end of the summer to achieve flood control storage limits. This practice increases electrical energy generation during the summer, but it also reduces electrical capacity by decreasing head. To the extent possible, CVP operators attempt to pass all releases through the powerplants. During flood operations, however, releases from CVP reservoirs often exceed powerplant capacities. Because power production is subordinate to other project purposes and obligations, CVP facilities are operated to optimize power only when more critical water operations would not be affected.

The quality of water released from CVP reservoirs is generally excellent. Releases from CVP facilities are made to maintain water quality conditions both instream and in the Delta in order to provide conditions consistent with fish and wildlife requirements and to protect M&I and agricultural beneficial uses.

Streamflow Criteria

Streams below CVP dams support both resident and anadromous fisheries. While resident fisheries are affected by release fluctuations, the anadromous fisheries (e.g., salmon and steelhead) are usually more sensitive and are present in some CVP streams year round. Maintaining water conditions favorable to spawning, incubation, rearing, and outmigration of the young anadromous fish is one of the main concerns of CVP operators. During spawning and incubation life stages, an attempt is made to establish project releases that can be sustained until the eggs hatch. If releases are reduced and the redds are dewatered, the eggs often may die. However, if the initial release levels are too low and large increases in flow are required, scouring of the channel can wash away the redd. CVP activities are coordinated to anticipate and avoid streamflow fluctuations during spawning and incubation whenever possible.

After the eggs have hatched and the juveniles are ready to begin the outmigration to the ocean, their migration can be assisted with increased flows, which can result from increased releases from

CVP and non-CVP reservoirs. Reclamation coordinates the operation of CVP reservoirs with DFG and the Service to schedule releases that create pulse flows to help "push" the fish downstream. Outmigration pulse flows are believed to reduce predation and minimize entrainment at Delta pumping plants.

In the management of releases prescribed by the COE for flood control, CVP operators have some latitude in controlling the magnitude and duration of the releases, based on concerns for downstream public safety and levee stability. Flood control releases are typically accomplished through a series of stepped increases defined by such factors as powerplant capability, minor flooding of adjacent lands, erosion, and channel capacity. Flood releases are established at the lowest step of the progression that will satisfy the requirements for evacuating storage, maximizing public safety, and minimizing the downstream effect of flood releases. When the threat of flooding subsides, releases are decreased according to specific rates prescribed by the COE to avoid sloughing of levee embankment materials and potential levee failure. Although high releases can effectively block access for fishing on the Trinity and American rivers and may make rafting on the American River unsafe, flood control operations and other constraints limit the opportunity to modify CVP operations strictly for recreation purposes.

Seepage can be a problem on the Sacramento and Stanislaus rivers but is typically not a concern on the Trinity or American rivers. During periods of prolonged elevated flows, which can result from flood control releases from CVP dams, downstream subsurface water can seep from the channel, causing high groundwater levels and sometimes surface-water flooding on adjacent lands. Prolonged periods of high groundwater in agricultural areas can diminish yield and can drown a crop. During wet years, seepage problems are difficult to avoid. To avoid exacerbating the situation in the Sacramento River Basin, imports of water from the Trinity River to the Sacramento River are minimized during periods of flood control releases unless public safety on the Trinity River is threatened.

Cold water conservation is particularly important during periods of drought, because water temperatures are higher when reservoir storage levels and streamflows are low, and warm water releases from reservoirs can have an adverse effect on reproduction of salmon. The SWRCB established temperature criteria in 1990 for the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam. The RWQCB established water temperature criteria between Lewiston Dam and the confluence of the North Fork of the Trinity River.

In 1993, NMFS in formal consultation issued a Long-term Winter-Run Chinook Salmon Biological Opinion that specifies flow and temperature requirements in the Sacramento River and provides guidelines for the operation of CVP facilities. CVP operations meet Sacramento River temperature criteria by mixing Shasta Lake and Clair Engle Lake water and/or regulating quantities to be released.

Water Rights in the Delta

Riparian water rights in the Delta total approximately 1.3 million acre-feet annually. Monthly diversions typically follow a pattern of minimum diversions in the winter and maximum diversions in the summer. Use of water pursuant to these rights varies from year to year and peak in July at approximately 270,000 acre-feet per year. Releases from both CVP and SWP reservoirs are required to meet these diversions when uncontrolled runoff cannot satisfy them.

REGULATIONS AND AGREEMENTS THAT AFFECT CVP OPERATIONS

The operation of the CVP is, and has historically been, affected by the provisions of several regulatory requirements and agreements. Prior to the passage of CVPIA, the operation of the CVP was affected by SWRCB Decisions 1422 and 1485, and the Coordinated Operations Agreement (COA). Decisions 1422 and 1485 identify minimum water flow and water quality conditions at specified locations, which are to be maintained in part through the operation of the CVP. The COA specifies the responsibilities between the CVP and SWP for meeting the requirements of D-1485. Regulation and agreements that affect the operations of specific CVP facilities are discussed in a later section of this document.

Beginning in 1987, a series of actions by the SWRCB, EPA, NMFS, and the Service affected interim water quality standards in the Delta. However, at the time CVPIA was enacted (October, 1992), the water quality standard in the Delta remained D-1485, and the CVP and SWP were operated in accordance with the COA to maintain this requirement.

In 1993, NMFS in formal consultation issued a Long-term Winter-Run Chinook Salmon Biological Opinion, which addresses modifications to the long-term CVP operational plan to avoid jeopardizing the continued existence of the Sacramento River winter-run chinook salmon. Also in 1993, the Service released a biological opinion on the effects of operational actions by the CVP and SWP on Delta Smelt and associated habitat. This biological opinion was revised in 1994 and in 1995.

In December 1994, representatives of the State and Federal governments and urban, agricultural and environmental interests agreed to the implementation of a Bay-Delta protection plan through the California State Water Resources Control Board (SWRCB), in order to provide ecosystem protection for the Bay-Delta Estuary. The Draft Bay-Delta Water Control Plan, released in May 1995, superseded D-1485.

SWRCB Decision 1422

D-1422, issued in 1973 and SWRCB Order 83-3, issued in 1983, hereinafter collectively referred to as D-1422, provided the primary operational criteria for New Melones Reservoir on the Stanislaus River and included a provision for water quality conditions on the San Joaquin River at Vernalis. In addition, D-1422 permitted Reclamation to appropriate water in New Melones Reservoir for purposes of agricultural irrigation, M&I uses, fish and wildlife enhancement, flood control, and maintenance of water quality conditions on the Stanislaus River. A detailed discussion of D-1422, and its affects on the operations of New Melones Reservoir, is provided in the decision of Eastside Division facilities and operations.

SWRCB Decision 1485

In 1978, the SWRCB adopted D-1485 for protection of beneficial uses in the Delta and to outline the responsibilities of the two largest exporters in the Delta, the CVP and the SWP. The SWRCB concurrently issued a Delta Water Quality Control Plan (Delta Plan) and an Environmental Impact Report on the Delta Plan. The basis for the D-1485 and the Delta Plan is that water quality is to be maintained at least to a level that would have existed if the CVP and SWP were not implemented. D-1485 includes flow, water quality, and export standards to protect the beneficial uses in the Delta. These standards are implemented by the SWRCB by including them in the water rights permits of the CVP and SWP.

Because of the hydraulic characteristics of the Delta, some D-1485 standards are managed more efficiently through export curtailments, while others are managed more efficiently through flow increases. Typically, operations to meet the water quality standards specified by D-1485 and D-1422 result in Delta water quality conditions that satisfy the requirements specified in CVP contracts (known as the Tracy Standards).

Coordinated Operations Agreement

The CVP and SWP use the Sacramento River and the Delta as common conveyance facilities, and therefore the operations of both of these projects can affect water quality conditions in the Delta. The 1986 COA between Reclamation and the DWR established the rationale for the coordination of reservoir releases and Delta exports between the CVP and SWP. The COA defines conditions under which existing in-basin and in-Delta demands are met, and establishes shared responsibilities of the CVP and SWP in meeting these requirements. The purpose of the COA is to ensure that each project receives its share of the available water supply and bears its share of the joint responsibilities to protect beneficial uses. The COA was established based on the water quality objectives specified in D-1485, and serves as technical reference for review and modification of sharing principles if and when Delta standards are modified by the SWRCB or new facilities or projects affect the hydrologic conditions in the Delta.

Balanced water conditions are defined in the COA as periods when the two projects agree that releases from upstream reservoirs plus unregulated flows approximately equal the water supply needed to meet Sacramento Valley in-basin uses plus exports. During balanced conditions, the two projects share in meeting in-basin uses. Two sharing arrangements are possible under the COA, depending on whether water from upstream CVP/SWP storage is required to meet Sacramento Valley in-basin uses, or if water associated with non-CVP/SWP regulated flow plus unregulated flow into the Delta is available for export. When water must be withdrawn from reservoir storage to meet Sacramento Valley in-basin requirements, 75 percent of the water is provided by the CVP, and 25 percent is provided by the SWP. When water from non-CVP/SWP sources and unregulated flow into the Delta is available for export in the Delta, the sum of CVP storage gains, SWP storage gains, and the available flow for export in the Delta is apportioned on a 55 percent to CVP and 45 percent to SWP basis. The COA further specifies that if one party cannot use its share of available water, the other party may use the available water.

When the Delta is out-of-balance, i.e., the Delta has excess water under the COA, there is, by definition, sufficient water to meet all Delta beneficial use standards. The COA provides that under these conditions the CVP and SWP can store and export as much water as possible within physical and contractual limits.

Winter-Run Chinook Salmon Biological Opinion

In 1992, the NMFS, in formal consultation with Reclamation, issued a specific one-year biological opinion for the protection of Sacramento River winter-run chinook salmon. In 1993, NMFS in formal consultation issued a long-term Winter-Run Chinook Salmon Biological Opinion, which addresses modifications to the long-term CVP operational plan to avoid jeopardizing the continued existence of the Sacramento River winter-run chinook salmon. In the development of both of these opinions, NMFS coordinated with DWR, the Service, DFG, and the SWRCB.

As a condition of the 1993 Long-Term Biological Opinion, Reclamation maintains a minimum flow of 3,250 cfs in the Sacramento River below Keswick Dam from October 1 through March 31. This minimum instream flow is required to provide safe rearing and downstream passage of winter-run chinook salmon, and to protect against the stranding of juveniles. When drought conditions threaten human health and safety, NMFS would consider variation from this requirement through reconsultation on a case-by-case basis. Under such circumstances, NMFS would consider how well accretions from tributary streams would preclude stranding of juvenile fish under reduced flows.

In accordance with the Biological Opinion, Reclamation attempts to maintain the daily average water temperature in the Sacramento River at no more than 56 degrees Fahrenheit within the winter-run chinook salmon spawning grounds below Keswick Dam. This temperature is required because winter-run chinook eggs and pre-emergent fry require temperatures at or below 56 degrees Fahrenheit for survival during the late June through August incubation period. The time period and exact river location are dependent upon operational environmental conditions, as calculated by Reclamation. At times when Reclamation cannot maintain temperature at the desired location, NMFS reinitiates consultation.

The Biological Opinion specifies that, beginning in September 1994, gates at the Red Bluff Diversion Dam must be in the raised position between September 15 and May 14. This mode of operation results in reduced diversions to the Tehama-Colusa Canal during the spring, summer, and fall. On April 1, 1996, the SWRCB issued a water rights order permitting the release of up to 38,293 acre-feet annually from Black Butte Reservoir for re-diversion through the constant head orifice to the Tehama-Colusa Canal from April 1 to May 15, and from September 15 and October 29.

In accordance with requirements in the 1993 Long-term Winter-Run Chinook Salmon Biological Opinion, Reclamation maintains the DCC gates in the closed position from February 1 through April 30 to reduce the diversion of juvenile winter-run chinook salmon emigrants into the Delta. Studies by the Service have indicated that the diversion of juvenile chinook salmon into the central portion of the Sacramento-San Joaquin Delta via the DCC and Georgiana Slough has a significant adverse impact on their survival.

Bay-Delta Plan Accord

In December 1994, representatives of the State and Federal governments and urban, agricultural and environmental interests agreed to the implementation of a Bay-Delta protection plan through the California State Water Resources Control Board (SWRCB), consistent with a set of Principles for Agreement, to provide ecosystem protection for the Bay-Delta Estuary. The purpose of the Bay-Delta Plan Accord is to establish water quality control measures that contribute to the protection of beneficial uses in the Bay-Delta Estuary, including objectives for salinity, water project operations, and dissolved oxygen. The protected beneficial uses include M&I, agriculture, and fish and wildlife. The CVP and SWP are operated under the Bay-Delta Plan Accord as defined in SWRCB Order 95-06.

The May 1995 Draft Water Quality Control Plan (WQCP) includes water quality objectives for the reasonable protection of M&I uses from salinity intrusion. These objectives are year-type based maximum chloride concentration standards for various compliance locations within the Delta. Water quality objectives are also included for the reasonable protection of agricultural uses from salinity intrusion and agricultural drainage in the western, interior, and southern Delta. These objectives are year-type based maximum salinity concentration standards at various compliance locations within the Delta.

The WQCP also includes water quality objectives in the WQCP are for the protection of fish and wildlife uses in the Bay-Delta estuary. Objectives are established for dissolved oxygen, salinity, Sacramento and San Joaquin river flows, Delta outflow, export limits, and Delta Cross Channel gate operations. Delta outflow objectives are for the protection of estuarine habitat for anadromous fishes and other estuarine-dependent species. Sacramento and San Joaquin river flow objectives are to provide attraction and transport flows and suitable habitat for various life stages of aquatic organisms, including Delta smelt and chinook salmon.

Objectives for export limits are included to protect the habitat of estuarine-dependent species by reducing the entrainment of various life stages by the major export pumps in the southern Delta. An objective for closure of the Delta Cross Channel gates is included to reduce the diversion of aquatic organisms into the interior Delta where they are more vulnerable to entrainment by the major export pumps and local agricultural diversions.

In 1995, following release of the WQCP, NMFS issued an amendment to the long-term winter run chinook salmon biological opinion. The QWEST requirements in the NMFS opinion were converted to export/inflow ratios to give equivalent protection for winter-run chinook salmon. The Service issued a similar revision to the 1994 delta smelt biological opinion, and further determined that the long-term combined CVP and SWP operations as modified by the winter-run biological opinion, the Principles for Agreement and WQCP are not likely to jeopardize the continued existence of the delta smelt or modify the critical habitat for delta smelt.

OPERATIONS OF CVP DIVISIONS AND FACILITIES

The facilities included in CVP divisions north of the Delta, including the Trinity, Shasta, and Sacramento River divisions, are shown schematically in Figure II-15. These divisions are known collectively as the Northern CVP System. Facilities in CVP divisions south of the Delta are shown in Figure II-16. Of these, the Delta, West San Joaquin, and San Felipe divisions are known collectively as the Southern CVP System. Both the East Side and Friant divisions, also shown in Figure II-15, are operated independently of the remainder of the CVP, due to the nature of their water supplies and service areas. The Northern and Southern CVP Systems are operated as an integrated system, and demands for water and power can be met by releases from any one of several facilities. Demands in the Delta and south of the Delta can be met by the export of excess water in the Delta, which can result from releases from northern CVP reservoirs. As a result, operational decisions are based on a number of physical and hydrological factors that tend to change depending on conditions.

Trinity River Division

The Trinity River Division, completed in 1964, includes facilities to collect and regulate water in the Trinity River, as well as facilities to transfer portions of the collected water to the Sacramento River Basin. Specific facilities in the Trinity River Division include Trinity Dam and Powerplant; Clair Engle Lake; Lewiston Dam, Lake, and Powerplant; Clear Creek Tunnel; Whiskeytown Dam and Lake; Spring Creek Debris Dam and Reservoir; and the Cow Creek Unit.

Trinity Dam is located on the Trinity River and regulates the flow from a drainage area of approximately 720 square miles. The dam was completed in 1962, forming Clair Engle Lake, with a maximum storage capacity of approximately 2.4 million acre-feet per year. All releases from Trinity Dam are re-regulated downstream at Lewiston Lake to meet downstream flow, in-basin diversion, and downstream temperature requirements. Lewiston Reservoir provides a forebay for the trans-basin transfer of water through the Clear Creek Tunnel and the Judge Francis Carr Powerplant into Whiskeytown Lake on Clear Creek.

Water stored in Whiskeytown Lake includes exports from the Trinity River as well as runoff from the Clear Creek drainage area. Releases from Whiskeytown Lake are either passed through the Spring Creek Powerplant and discharged into Keswick Reservoir on the Sacramento River or released to Clear Creek to meet downstream flow and diversion requirements.

The mean annual inflow to Clair Engle Lake from the Trinity River is about 1.2 million acre-feet per year, a large percentage of which is diverted to the Central Valley. Clair Engle Lake is operated to satisfy required fishery releases to the Trinity River, while attempting to fill the lake by the end of June to maximize power production during the summer and fall. During the winter months, Clair Engle Lake storage is regulated within the capacity of Trinity, Lewiston, Spring Creek, Judge Francis Carr, and Keswick powerplants, as well as Reclamation's Safety of Dams criteria.

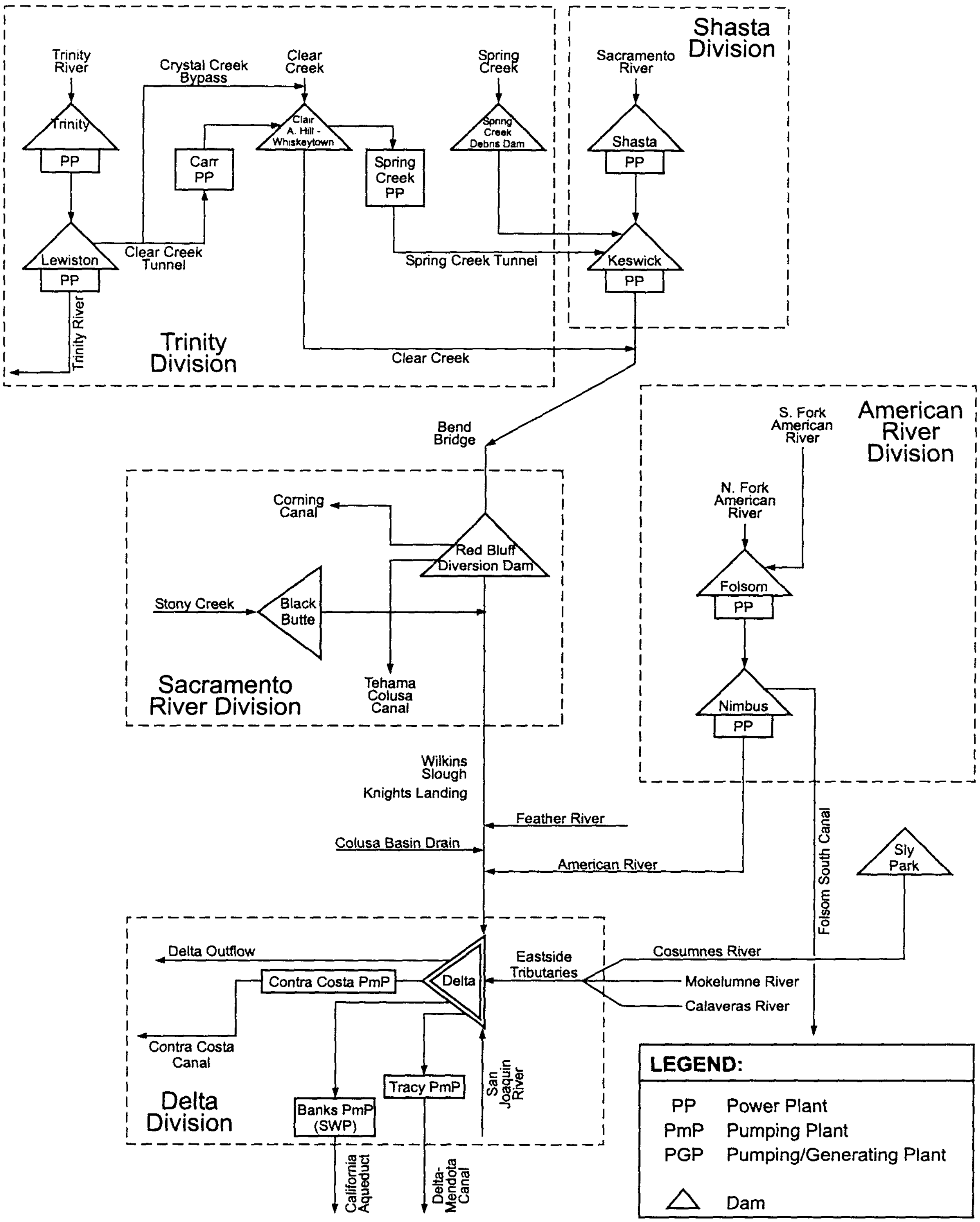


FIGURE II-15

CENTRAL VALLEY PROJECT FACILITIES NORTH OF THE DELTA

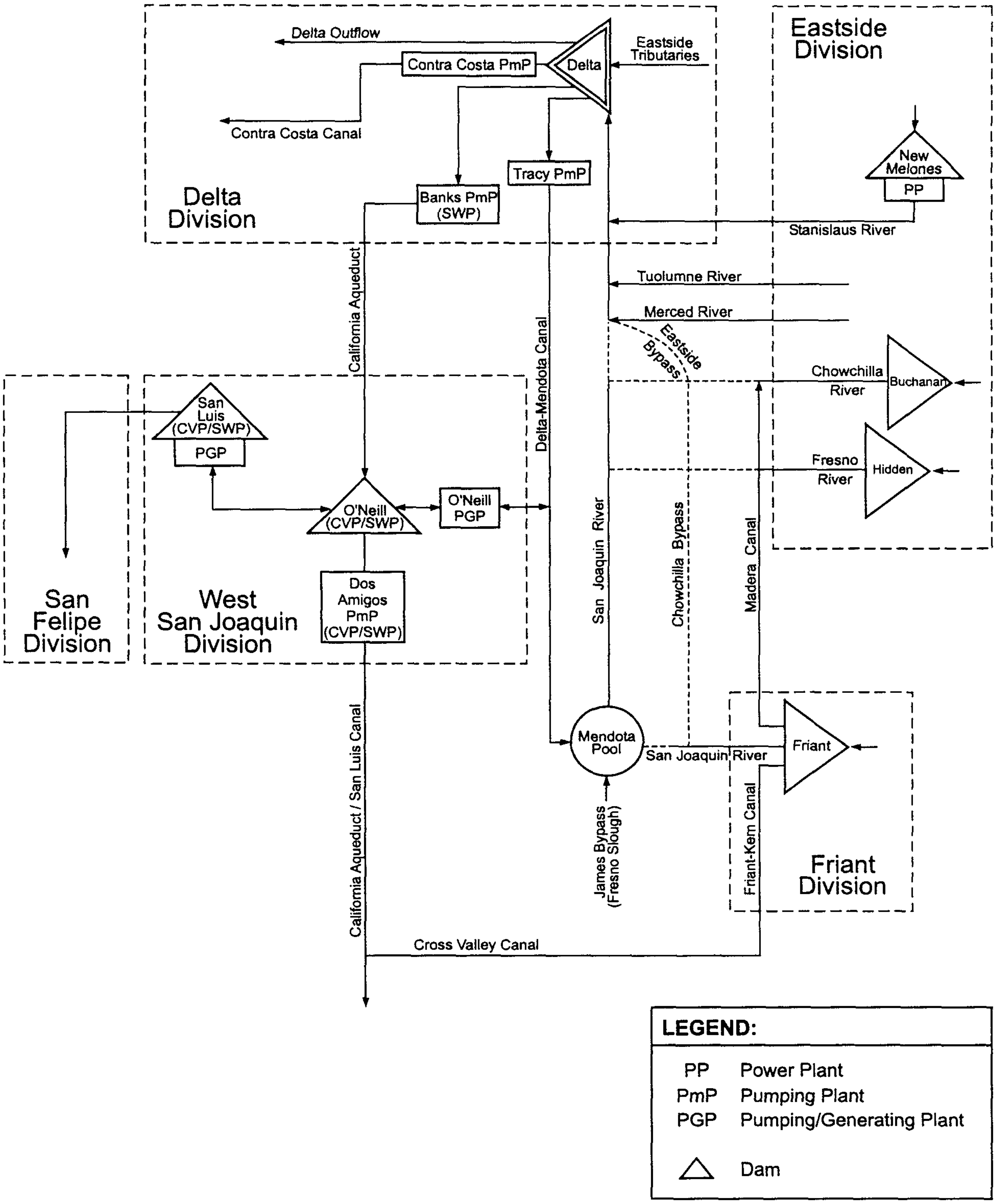


FIGURE II-16

CENTRAL VALLEY PROJECT FACILITIES SOUTH OF THE DELTA

C–080159

Fish and Wildlife Requirements on the Trinity River. The Secretary of the Interior has authority under the Trinity River Act of 1955 to mitigate losses of fish resources and habitat. The legislation mandates that the operation of the Trinity Division be integrated and coordinated with the operation of other CVP features to realize the fullest, most beneficial, and most economic use of the water resources. When Trinity Reservoir began operations in 1963, total annual releases downstream from Lewiston Dam were to be at a minimum of 120,500 acre-feet per year Since 1963, salmon and steelhead runs in the Trinity River have severely declined.

On May 8, 1991, the Secretary of the Interior endorsed a position statement developed by the Assistant Secretaries for Fish, Wildlife, and Parks; Indian Affairs; and Water and Science. This position statement required releases from Lewiston Dam to the Trinity River flows as follows.

- in water year 1991, releases between 240,000 and 340,000 acre-feet per year, based on inflow into Shasta Lake and a ramping formula; and
- in water years 1992 through 1996, releases of at least 340,000 acre-feet per year in dry or wetter water years and 340,000 acre-feet per year in critical dry years, if possible.

Release schedules are developed annually in consultation with the Service, based on conditions as of February 1.

Temperature objectives for the Trinity River vary by reach and by season. Between Lewiston Dam and Douglas City Bridge, the daily average temperature cannot exceed 60 degrees Fahrenheit from July 1 to September 14 and 56 degrees Fahrenheit from September 15 to October 1. From October 1 to December 31, the average daily temperature cannot exceed 56 degrees Fahrenheit between Lewiston Dam and the confluence of the North Fork Trinity River.

Fish and Wildlife Requirements on Clear Creek. Water Rights permits issued by SWRCB for diversions from Trinity River and Clear Creek specify minimum downstream releases from Lewiston and Whiskeytown dams, respectively. Two agreements govern releases from Whiskeytown Lake.

- A 1960 Memorandum of Agreement (MOA) with DFG establishing the following minimum flows to be released to Clear Creek at Whiskeytown Dam.

January 1 through February 28,29	50 cfs
March. 1 through May 31	30 cfs
June 1 through September 30	0 cfs
October 1 through October 15	10 cfs
October 16 through October 31	30 cfs
November 1 through December 31	100 cfs

- A 1963 release schedule from Whiskeytown Dam developed and implemented (but never formalized) with the Service to enhance fishery and recreational values for the Whiskeytown National Recreation Area.

January 1 through October 31	50 cfs (normal year), and 30 cfs (critical year)
November 1 through December 31	100 cfs (normal year), and 70 cfs (critical year)

Hydropower. Power production as a result of cross-basin diversion of Trinity River water through Trinity powerplants is approximately three to five times as efficient as power production at Shasta and Sacramento River Division powerplants. Clair Engle Lake usually reaches its greatest storage level at the end of June annually. This allows the maximum volume and head possible can be used too generate power at the Trinity, Carr, and Spring Creek powerplants when it is most needed. This operation affects releases into Keswick Reservoir and therefore also affects Shasta operations.

Recreation. Though not an authorized purpose of the Trinity Division, recreational use of Clair Engle Lake, Lewiston Reservoir, and Whiskeytown Lake, and on the Trinity River is significant. Recreational considerations are factored into operational decisions that may result in abnormal reservoir levels or river flows. In general, the use of recreational facilities is typically constrained during dry or critically dry conditions only.

Flood Control. Flood control is not an authorized purpose of the Trinity River Division, although flood control benefits are provided through normal operations. Trinity Dam was not authorized for flood control and has limited release capacity below the spillway crest elevation. Studies completed by COE in 1974 and Reclamation in 1975 showed that the spillway and outlet works at Trinity Dam are not sufficient to safely pass the inflow design flood. Therefore, Safety of Dams criteria stipulate that drawdown and controlled filling of Clair Engle Lake are necessary to keep the storage from exceeding the total storage capacity. The regulation of storage is accomplished with releases that are within Trinity and Carr powerplant capacities and by minimizing releases to the Trinity River that exceed the requirements for fisheries.

A minimum storage reservation of 348,000 acre-feet per year is maintained in Clair Engle Lake from November through March. During a major flood, releases from Trinity Dam are restricted to the combined capacity of the powerplant and outlet works until a spill occurs. The release to the Trinity River at Lewiston Dam is reduced by diversions through Clear Creek Tunnel to Whiskeytown Lake, unless flood conditions on Clear Creek or on the Sacramento River require the diversion to be suspended.

Whiskeytown Lake is operated to maintain approximately 35,000 acre-feet per year of storage space during the flood season. Whiskeytown Lake operations during major floods are complicated by its relationship with the Trinity, Shasta, and Sacramento River operations. A number of specific operating guidelines have been developed to guide operations during this period.

Shasta and Sacramento River Divisions

The Shasta Division of the CVP includes facilities that conserve water on the Sacramento River for flood control, navigation maintenance, conservation of fish in the Sacramento River, protection of the Delta from intrusion of saline ocean water, irrigation and M&I water supplies, and hydroelectric generation. The Shasta Division includes Shasta Dam, Lake, and Powerplant; Keswick Dam, Reservoir, and Powerplant; and the Toyon pipeline.

The Sacramento River Division, which was authorized after completion of the Shasta Division, includes facilities for the diversion and conveyance of water to CVP contractors on the west side of the Sacramento River. The division includes the Sacramento Canals Unit, which was authorized in 1950 and consists of the Red Bluff Diversion Dam, the Corning Pumping Plant, and the Corning and Tehama-Colusa canals. The unit was authorized to supply irrigation water to over 200,000 acres of land in the Sacramento Valley, principally in Tehama, Glenn, Colusa, and Yolo counties. Black Butte Dam, operated by the COE, also provides supplemental water to the Tehama-Colusa Canal, as it crosses Stony Creek. The operations of Shasta and Sacramento River divisions are presented together because of their operational inter-relationships.

Shasta Dam is located on the Sacramento River at the confluence of the Sacramento, McCloud, and Pit rivers, and regulates the flow from a drainage area of approximately 6,649 square miles. The dam was completed in 1945, forming Shasta Lake, with a maximum storage capacity of 4,552,000 acre-feet per year. Water in Shasta Lake is released through or around the Shasta Powerplant to the Sacramento River, where it is re-regulated downstream by Keswick Dam. A small amount of water is diverted directly from Shasta Lake for M&I use by local communities.

Keswick Reservoir, formed by the completion of Keswick Dam in 1950, has a capacity of approximately 23,800 acre-feet per year and serves as an afterbay for releases from Shasta Dam, and for discharges from the Spring Creek Powerplant. All releases from Keswick Reservoir are made to the Sacramento River at Keswick Dam. The dam has a migratory fish trapping facility that operates in conjunction with the Coleman National Fish Hatchery on Battle Creek.

During the construction of Shasta Dam, the Toyon Pipeline was constructed to supply water from the Sacramento River to the camp used to house the workers at Toyon. The pipeline remains in use today, supplying municipal water to small communities in the area.

The Red Bluff Diversion Dam, located on the Sacramento River approximately 2 miles southeast of Red Bluff, diverts water to the Corning and Tehama-Colusa canals. Completed in 1964, the dam is a gated structure with fish ladders at each abutment. The gates are lowered during the spring to impound water for diversion, and raised in the fall to allow the river flow through. When the gates are lowered, the impounded water creates Lake Red Bluff. Since 1988, the dam gates have been raised during winter months to allow passage of the winter-run chinook salmon, and diversions have been made through a pilot pumping plant. Recently (after October 1992), at times when this pumping capacity was not adequate to meet water demands, some water has been made available from Black Butte Reservoir.

Construction of the Tehama-Colusa Canal began in 1965. The canal extends 113 miles southerly from the Red Bluff Diversion Dam to provide irrigation service on the west side of the Sacramento Valley in Tehama, Glenn, Colusa, and northern Yolo counties, and is operated by the Tehama-Colusa Canal Authority. The Corning Pumping Plant lifts water approximately 56 feet from the Tehama-Colusa Canal into the 21-mile-long Corning Canal. The Corning Canal was completed in 1959 to serve water to CVP contractors in Tehama County that cannot be served by gravity from the Tehama-Colusa Canal. A portion of the water delivered in the Tehama Colusa

Canal service area is provided through the South Canal, which conveys water released from the COE Black Butte Dam to Stony Creek.

Construction of the Temperature Control Device (TCD) at Shasta Dam was completed in 1997. This device is designed to allow greater flexibility in the management of cold water reserves in Shasta Lake while enabling hydroelectric power generation. The TCD is designed to enable releases of water from varying lake levels through the power plant to attempt to maintain adequate water temperatures in the Sacramento River downstream of Keswick Dam. Prior to construction of the Shasta TCD, reclamation had made releases from Shasta Dam's low-level powerplants bypass outlet to provide cooler water and alleviate high water temperature during critical periods of the spawning and incubation life stages of the winter-run chinook stock. Releases through the low-level outlets bypass the powerplant and result in a loss of hydroelectric generation at the Shasta Powerplant. Because the temperature control device was under construction during the preparation of the PEIS, there has been no operational experience to evaluate its effectiveness. For the purposes of the PEIS, it is assumed that the device will operate as designed, and will thereby allow Reclamation to more effectively meet the temperature requirements of the winter run chinook salmon biological opinion.

Fish and Wildlife Requirements on the Sacramento River. Reclamation operates the Shasta, Sacramento River, and Trinity River divisions of the CVP to meet, to the extent possible, the provisions of SWRCB Order 90-05 and the winter-run chinook biological opinion. Flow objectives in the Sacramento River had been previously established in an April 5, 1960 Memorandum of Agreement (MOA) between Reclamation and DFG, for the protection and preservation of fish and wildlife resources in the Sacramento River. The agreement provided for minimum releases into the natural channel of the Sacramento River at Keswick Dam for normal and critical dry years.

Historically, elevated water temperature in the upper Sacramento River has been recognized as a key factor in the decreasing population of chinook salmon stocks that inhabit the river. Temperature on the Sacramento River system is influenced by several factors, including the relative temperatures and ratios of releases from Shasta Dam and from the Spring Creek Powerplant. The temperature of water released from Shasta Dam and the Spring Creek Powerplant is a function of the total storage at Shasta and Clair Engle lakes, the depths from which releases are made, the percent of total releases from each depth, ambient air temperatures and other climatic conditions, tributary accretions and temperatures, and residence time in Keswick and Lewiston reservoirs, and in the Sacramento and Trinity rivers.

SWRCB Water Rights Orders 90-05 and 91-01. In 1990 and 1991, SWRCB issued Water Rights Orders 90-05 and 91-01 modifying Reclamation's water rights for the Sacramento River. The orders include temperature objectives for the Sacramento River and state that Reclamation shall operate Keswick and Shasta dams and the Spring Creek powerplants to meet a daily average water temperature of 56 degrees Fahrenheit at Red Bluff Diversion Dam in the Sacramento River during periods when higher temperature would be harmful to the fishery. Under the orders, the compliance point may be changed when the objective cannot be met at the Red Bluff Diversion Dam. In addition, Order 90-05 modified the minimum flow requirements in the Sacramento River below Keswick Dam initially established in the MOA.

Since October 1981, Keswick Dam has been operated based on a minimum release of 3,250 cfs for normal years from September 1 through the end of February, in accordance with an agreement between Reclamation and DFG. This release schedule was included in Order 90-05, which maintains a minimum release of 3,250 cfs at Keswick Dam and Red Bluff Diversion Dam from September through the end of February in all water years except critical dry years. A summary of minimum flows below Keswick Dam for normal years and critical dry years, as specified in the MOA and modified by Order 90-05 is shown in Table II-4.

The 1960 MOA provides that releases from Keswick Dam from September 1 through December 31 are made with a minimum of fluctuation or change if protecting the salmon is compatible with other operations requirements. Releases from Shasta and Keswick dams are gradually reduced in September and early October during the transition from meeting Delta export and water quality demands to operating the system for flood control from October through December.

Reclamation usually attempts to reduce releases from Shasta and Keswick dams to the minimum fishery release requirement by October 15 each year and to minimize changes in releases from Keswick Dam between October 15 to December 31. Releases may be increased during this period to meet unexpected downstream needs, such as higher outflows in the Delta to meet water quality requirements or to meet flood control requirements. Releases from Keswick Dam may be reduced when downstream tributary inflows increase to a level that will meet flow needs. To avoid release fluctuations, the base flow is selected to achieve the desired target storage levels in Shasta Lake from October through December.

TABLE II-4

MINIMUM FLOW REQUIREMENTS ON THE SACRAMENTO RIVER BELOW KESWICK DAM

Period	MOA Normal Years	WR 90-05 Normal Years	MOA and WR 90-05 Critical Dry Years
January 1 through February 28	2,600 cfs	3,250 cfs	2,000 cfs
March 1 through August 31	2,300 cfs	2,300 cfs	2,300 cfs
September 1 through November 30	3,900 cfs	3,250 cfs	2,800 cfs
December 1 through December 31	2,600 cfs	3,250 cfs	2,000 cfs

Recreation. Although not an authorized purpose, recreational use of Shasta Lake is significant with the prime recreation season extending from Memorial Day through Labor Day. It is desirable to have Shasta Lake full by Memorial Day and no less than elevation 1,017 feet on Labor Day. This elevation corresponds to a drawdown of 50 feet below the top of the conservation pool and is just below the bottom of the flood control storage envelope. The drawdown rate varies but is typically high during July in response to irrigation demands and during August in response to irrigation demands and temperature control operations. Customary patterns of storage and release typically result in acceptable water levels during the prime recreation season. Storage typically peaks in May, and significant drawdown usually does not occur until July and August. During drought periods, recreation opportunities at Shasta Lake are reduced because of the drawdown required to meet CVP uses.

The seasonal operation patterns at Keswick Dam typically are sufficient to satisfy river recreation needs. During flood control operations, little recreational use occurs along the river. In the spring and fall, marinas in the Sacramento area have occasionally reported shallow water problems at low flows.

Flood Control. Flood control objectives for Shasta Lake require that releases be restricted to quantities that will not cause downstream flows or stages to exceed specified levels. These include:

- a flow of 79,000 cfs at the tailwater of Keswick Dam
- a stage of 39.2 feet in the Sacramento River at Bend Bridge gauging station, which corresponds to a flow of approximately 100,000 cfs

Flood control operations are based on regulating criteria developed by the COE pursuant to the provisions of the Flood Control Act of 1944. Maximum flood space reservation is 1.3 million acre-feet per year, with variable storage space requirements based on the current flood hazard. Flood control operations at Shasta Lake require forecasts of flood runoff both upstream and downstream from Shasta as far in advance as possible.

The most critical CVP flood forecast for the Sacramento River is that of local runoff entering the Sacramento River between Keswick Dam and Bend Bridge. The travel time required for release changes at Keswick Dam to affect Bend Bridge flows is approximately 8 to 10 hours. If flow at Bend Bridge is projected to exceed 100,000 cfs, the release from Keswick Dam is decreased so that the 100,000 cfs flow at Bend Bridge is not exceeded. As the flow at Bend Bridge is projected to recede, the Keswick Dam release is increased to evacuate water stored in the flood control space at Shasta Lake. Changes to Keswick Dam releases are scheduled to minimize rapid fluctuations in the flow at Bend Bridge.

Navigation Minimum Flow. Historical commerce on the Sacramento River resulted in the requirement to maintain minimum flows of 5,000 cfs at Chico Landing to support navigation. There is currently no commercial traffic between Sacramento and Chico Landing, and the COE has not dredged this reach to preserve channel depths since 1972. However, over time, water users diverting from the river have set their pump intakes just below this level. Therefore, the CVP is operated to meet the navigation flow requirement of 5,000 cfs at Wilkins Slough under all but the most critical water supply conditions to facilitate pumping.

Seepage and Drainage Problems in the Sacramento River. Reclamation has completed numerous studies, concluding that high stages in the river can result in seepage flow under levees. While other factors, including flood-plain topography and stratigraphy, can influence seepage, the height and duration of the river stage above the level of the adjacent land are major contributors to the extent and severity of the seepage. Because the operations of Shasta and Keswick dams regulate a substantial portion of flow in the Sacramento River, these operations can affect seepage potential. In most years, Shasta Dam operations provide some degree of seepage control. However, because Shasta was not authorized specifically for controlling seepage, these benefits are considered incidental.

Widespread seepage damage might be expected to occur in those very wet years when inflow to Shasta Lake exceeds the 10-percentile level, particularly in years that have major flood events shortly before or during the irrigation season. When releases from Keswick Dam can be reduced in March and April to lessen seepage potential during those months, the threat of damage to crops is significantly reduced.

The effect of high flows in the Sacramento River can be intensified as a result of Trinity River Division operations. Because power is an authorized purpose of the CVP, and Trinity River Division in particular, diversions to the Sacramento River Basin are made when runoff cannot be stored in Clair Engle Lake. During the flood season, water is diverted to regulate storage in Clair Engle Lake while minimizing spills to the Trinity River. The diversion is minimized whenever the Sacramento River approaches or reaches flood stage, although during these periods the amount of water diverted from the Trinity River Basin is normally a small percentage of the total flow in the Sacramento River. If a spill is already occurring at Moulton and Colusa weirs, an increase in the release at Keswick Dam will have little impact downstream. If a spill is not occurring, the impact on increased stages will vary, depending on the width of the river channel. In exceptionally wet periods, the diversion is minimized during the spring as Clair Engle Lake is filled.

During September and October, farmers in the Sacramento Valley drain their rice fields. High stages in the Sacramento River can impede this drainage. The timing and amount of drainage flows entering the Sacramento River during rice field drainage is regulated by the RWQCB to limit the impact of pesticides and other chemical constituents in the drainwater. Drainage from the Colusa Basin Drain enters the Sacramento River near Knights Landing through a regulated outfall structure. When the Sacramento River is high, flows from the outfall structure can be restricted and water can back up in the drain causing flooding of agricultural lands.

Anderson-Cottonwood Irrigation District Diversion Dam Operations. The ACID Diversion Dam in Redding diverts water from the Sacramento River. Because this dam is a flashboard dam that is installed for seasonal use only, close coordination is required between Reclamation and ACID for regulation of river flows to allow safe installation and removal of the flashboards. ACID installs flashboards in the dam around April 1 each year and removes them around November 1. Installation and removal cannot be safely done when flows from Keswick Dam are greater than 6,000 cfs.

American River Division

The American River Division was authorized for construction by the COE and integration into the CVP by the American River Basin Development Act of 1949. The American River Division includes facilities that provide conservation of water on the American River for flood control, fish and wildlife protection, recreation, protection of the Delta from intrusion of saline ocean water, irrigation and M&I water supplies, and hydroelectric generation. Initially authorized features of the American River Division include Folsom Dam, Lake and Powerplant; Nimbus Dam, Powerplant and Lake Natoma; and the Sly Park Unit, which provides water from the Cosumnes River to EID. The Sly Park Unit includes Sly Park Dam, Jenkinson Lake, the Camino Conduit, and the EID Distribution System. The Auburn-Folsom South Unit of the American River Division was authorized in 1965 by Public Law 89-161 and includes the Foresthill Divide sub-unit and the Folsom South Canal. The Foresthill Divide sub-unit includes facilities for the storage and delivery of water to the town of Foresthill.

Folsom Dam was turned over to Reclamation for coordinated operation with other CVP facilities upon completion of construction by the COE in 1956. The dam and eight other dikes create Folsom Lake, with a total storage capacity of 972,000 acre-feet per year. Approximately 7 miles downstream, Nimbus Dam forms Lake Natoma, an afterbay used to re-regulate releases from Folsom Dam and to provide a diversion to the Folsom South Canal. The Folsom South Canal was designed to deliver water from Lake Natoma to M&I and irrigation users in Sacramento, San Joaquin, and Stanislaus counties. The first two reaches of the canal, extending to the Sacramento/San Joaquin county line just south of Highway 104, were completed in 1973. Construction of the remainder of the canal has been suspended pending reconsideration of alternatives. Releases from Nimbus Dam to the American River pass through the Nimbus Powerplant.

Fish and Wildlife Requirements on the American River. The Nimbus Fish Hatchery and the American River Trout Hatchery were constructed to compensate for the loss of riverine habitat caused by the construction of Folsom Dam. To help maintain natural fish production in the American River below Nimbus Dam, the American River Division facilities are operated to maintain minimum fishery flows and attempt to meet temperature objectives.

Releases from Nimbus Dam to the lower American River for minimum fish and recreation flows are variable, and are determined based on the available storage in Folsom Lake and hydrologic forecasting. This historical operational practice has been termed "Modified D-1400" operations because of the strategic desires to meet D-1400 minimum flow objectives when hydrologic conditions are supportive and to limit releases to D-893 minimum fish flow objectives during adverse hydrologic conditions. Minimum flows can range from 250 cfs in months with low Folsom Lake storage to 3,000 cfs in months with high Folsom Lake storage and hydrologic projections of ample runoff.

To provide stable flows for salmon spawning and incubation, fall flows in the lower American River are set in mid-October at a level that is expected to be maintainable, as a minimum, through February. Typically, fall and winter releases are set at levels between 1,000 cfs and 1,750 cfs, depending on Folsom Lake storage at the end of September and expected inflows from upstream reservoirs. These flows exceed current required minimum flows, as specified in D-893, which defines the current minimum flow on the American River at H Street to be 500 cfs from September 15 through December 31.

Temperature control problems are greatest at Folsom Lake, when the cold water pool is not large enough for either instream fishery needs or for the fish hatcheries downstream of Nimbus Dam. During some years, water temperatures are too high for both instream spawning and hatchery operations. When this occurs, hatchery production is transferred to other state hatcheries. Recently, operations of Shasta Dam to maintain required temperature conditions for the winter-run chinook salmon in the Sacramento River have reduced the operational flexibility to establish a substantial cold water reserve in Folsom Reservoir. This flexibility loss is particularly evident in dry years when efforts to create a cold water reserve at Shasta Lake during the spring results in lower-than-normal Keswick releases and higher-than-normal Nimbus releases to meet Delta obligations. Under this circumstances, Folsom storage in the fall may be lower than normal with a smaller cold water reserve and less capability to provide cold water releases.

Recreation. Both the lower American River and the lakes behind Folsom and Nimbus dams provide significant recreation opportunities, principally boating and fishing in the lakes and rafting and fishing in the river. If available water supplies allow, lake levels are maintained through Labor Day to provide access to boat launching ramps and marina facilities. In 1990, Folsom Lake was excavated in the vicinity of Brown's Ravine Marina to allow its use under lower storage conditions.

Flood Control. Flood control requirements and regulating criteria are specified by the COE and described in the Folsom Dam and Lake, American River, California Water Control Manual (COE, 1987).

From June 1 through September 30, no flood control storage restrictions exist. From October 1 through November 16 and from April 20 through May 31, reserving storage space for flood control is a function of the date only, with full flood reservation space required from November 17 through February 7. Beginning February 8 and continuing through April 20, flood reservation space is a function of both date and wetness.

In normal years, the focus of Folsom operations is on filling Folsom Lake near the end of May when flood control restrictions are lifted. In drier years, Folsom may be permitted to fill earlier as flood control restrictions are gradually eased.

Delta Division

Delta Division facilities provide for the transport of water through the Sacramento and San Joaquin rivers and the San Francisco Bay-Delta Estuary, and the conveyance of exported water through the San Joaquin Valley. The main features of the Delta Division are the Delta Cross Channel (DCC), the Contra Costa Canal, the Tracy Pumping Plant, and the Delta-Mendota Canal. Delta Division facilities are operated to supply water to CVP contractors served by the Contra Costa and Delta-Mendota canals. The Delta Division is also operated in conjunction with the SWP through the COA to meet the requirements of in-Delta riparian water rights holders and Delta water quality standards imposed by the SWRCB to protect beneficial uses of the Delta.

The DCC is a controlled diversion channel located between the Sacramento River and Snodgrass Slough, a tributary of the Mokelumne River in the Delta. Two gates control the flow of water from the Sacramento River through a short, excavated channel near Walnut Grove into the slough. From there it flows through natural channels in the central Delta to the Tracy Pumping Plant. The DCC gates are operated for water quality, fishery, recreation, and flood control purposes.

The Contra Costa Canal, one of the first CVP facilities, was completed in 1948. The canal was originally constructed to serve agricultural users in eastern and central Contra Costa County; however, urban growth and municipal demands have replaced nearly all of the original agricultural uses. As the uses of water changed, the canal was modified to improve service to contractors.

The Tracy Pumping Plant, completed in 1951, consists of an inlet channel, pumping plant, and discharge pipes that convey water from the Delta to the Delta-Mendota Canal. Fish salvaged at the Tracy Fish Screen, located in the intake channel, are transported by truck to release points at various locations in the Delta. The Delta-Mendota Canal, also completed in 1951, conveys CVP water from the Tracy Pumping Plant to the Mendota Pool on the San Joaquin River west of Fresno. The Delta-Mendota Canal operates at capacity for much of the year. The canal delivers water to San Joaquin River Exchange Contractors and CVP water service contractors in the San Joaquin Valley. A portion of the water conveyed through the Delta-Mendota Canal is pumped into the O'Neill Forebay and then into San Luis Reservoir. Water in San Luis Reservoir is held in storage to meet contract requirements for agricultural irrigation on the west side of the San Joaquin Valley and to deliver water to CVP contractors in the San Felipe Division.

Beneficial uses in the Delta are protected by the water quality standards of SWRCB Bay-Delta WQCP. DCC gate operations are also specified in the NMFS 1993 Long-term Winter-Run Chinook Salmon Biological Opinion. To accomplish these objectives, CVP and SWP operators must consider the current water supply and hydrologic conditions and current water quality conditions as well as potential impacts to fisheries, recreation, and power when making operational decisions. Operational actions to maintain Delta water quality are based on operational knowledge and past experience, current water quality and hydrodynamic conditions, and empirical studies. Operations are changed based on these data in an attempt to prevent non-compliance.

Delta Cross Channel Gate Operations. Closing the DCC gate increases the flow on the Sacramento River and can help meet downstream water quality standards. However, this action also reduces the amount of fresh water that passes south through the Delta toward the export pumping facilities. Without this additional water, reverse flow conditions can occur on the San Joaquin River, resulting in increased salinity intrusion near the Tracy Pumping Plant when the CVP and SWP export facilities are in operation. For this reason, the DCC gate can usually be closed for a couple of days only before deteriorating water quality on the San Joaquin River side of the Delta requires that it be reopened. In accordance with requirements in the 1993 Long-term Winter-Run Chinook Salmon Biological Opinion, Reclamation maintains the DCC gate in the closed position from February 1 through April 30 to reduce the diversion of juvenile winter-run chinook salmon emigrants into the Delta. Studies by the Service have indicated that the diversion of juvenile chinook salmon into the central portion of the Sacramento-San Joaquin Delta via the Cross Channel and Georgiana Slough has a significant adverse impact on their survival.

Tracy Pumping Plant Operations. The Tracy Pumping Plant, consisting of six constant speed units is operated to meet water demands south of the Delta. Changes in pump operations are typically performed early in the day to allow adequate time for operation and maintenance personnel to adjust check gates on the Delta-Mendota Canal during daylight hours. Partly because of the time involved in changing pump operations and the additional wear on the pumping units, frequent cycling of the units is normally avoided. The capacity of Tracy Pumping Plant is 4,600 cfs, which frequently unrealized because constraints along the Delta-Mendota Canal and at the relift pumps to O'Neill Forebay restrict export capacity to 4,200 cfs at that point.

West San Joaquin Division

The West San Joaquin Division of the CVP consists of the San Luis Unit, and includes federal as well as joint federal and State of California water storage and conveyance facilities that provide for delivery of water to CVP contractors in the San Joaquin Valley and in the San Felipe Division. Facilities in the West San Joaquin Division include San Luis Dam and Reservoir, O'Neill Dam and Forebay, the San Luis Canal, Coalinga Canal, Los Banos and Little Panoche detention dams and reservoirs, and the San Luis Drain.

San Luis Dam and Reservoir is located on San Luis Creek near Los Banos. The reservoir, with a capacity of 2.0 million acre-feet per year, is a pumped-storage reservoir primarily used to store water exported from the Delta. It is a joint federal and State of California facility that stores CVP and SWP water. Water from San Luis Reservoir is released to:

- the joint federal and state San Luis Canal to serve CVP and SWP contractors;
- through the Pacheco Tunnel to serve the San Felipe Unit of the CVP; and
- the Delta-Mendota Canal to serve CVP and exchange contractors on the east side of the San Joaquin Valley.

O'Neill Dam and Forebay are located on San Luis Creek downstream of San Luis Dam along the California Aqueduct. The forebay is used as a hydraulic junction point for state and federal waters. CVP water is lifted from the Delta-Mendota Canal to the O'Neill Forebay by the O'Neill Pumping-Generating Plant. CVP/SWP water from O'Neill Forebay is lifted to San Luis Reservoir by the joint CVP/SWP William R. Giannelli Pumping-Generating Plant. The forebay provides re-regulation storage necessary to permit off-peak pumping and on-peak power generation by the plant. When CVP water is released from O'Neill Forebay to the Delta-Mendota Canal, the units at the O'Neill Pumping-Generating Plant operate as generators.

The San Luis Canal, the joint federal and state (CVP/SWP) portion of the California Aqueduct, conveys water southeasterly from O'Neill Forebay along the west side of the San Joaquin Valley for delivery to CVP and SWP contractors. The Coalinga Canal conveys water from the San Luis Canal to the Coalinga area, where it serves the southern San Joaquin River Region. Water from the San Luis Canal is lifted at the Pleasant Valley Pumping Plant to the Coalinga Canal. Los Banos and Little Panoche detention dams and reservoirs protect the joint CVP/SWP San Luis

Canal by controlling flows of streams crossing the canal. These facilities do not supply water to the CVP or SWP.

The San Luis Drain was designed to carry agricultural return flows from collector drains along the west San Joaquin Valley and transport them to the Delta for discharge to the ocean, as specified in the authorization for the San Luis Unit. Initially the drain was planned as a joint state-federal facility; however, the state later declined to participate in the project. From 1975 to 1985, the San Luis Drain discharged to Kesterson NWR. During that time, selenium in soil sediments from upstream agricultural drainages was incidentally accumulated through biologic reduction at the Kesterson Reservoir. In 1982, the Service discovered high levels of selenium in fish collected from the reservoir. During the following year, waterfowl deformity was discovered at the reservoir. Subsequent investigations revealed that selenium concentrations were high in groundwater near the reservoir and in reservoir sediments, and the drain was closed. The operation of San Luis Drain ceased by June 1986, and the reservoir remains closed to drainage disposal. Reclamation began clean-up activities and waterfowl hazing shortly after the inflows to Kesterson ceased.

The management of San Luis Unit facilities is influenced by, and has substantial influence on, the management of northern CVP facilities. About half of the CVP's annual water supply is delivered through the Delta-Mendota Canal and San Luis Unit. To accomplish the objective of providing water to CVP contractors in the San Joaquin Valley, three conditions must be considered:

- water demands for CVP water service contractors and exchange contractors must be determined;
- a plan to fill and draw down San Luis Reservoir must be made; and
- plans for coordination of Delta pumping and San Luis Reservoir operations must be established.

State and Federal Coordination. The CVP operation of the San Luis Unit requires coordination with the SWP because some of the facilities are joint state and federal facilities. Similar to the CVP, the SWP also has water demands it must meet with limited water supplies and facilities. Coordinating the operations of the two projects avoids inefficient situations such as one entity pumping water into San Luis Reservoir at the same time the other is releasing water.

During spring and summer, water demands generally exceed the capability to pump water at these two facilities, and water stored in San Luis Reservoir is used. Because San Luis Reservoir has very little natural inflow, water is stored there when the Tracy and Banks pumping plants can export more water from the Delta than is needed for contracted water needs.

Adequate storage must be maintained in San Luis Reservoir to ensure delivery capacity to the San Felipe Division through the Pacheco Pumping Plant. During dry years when the SWP and CVP portions of San Luis storage are near their low points at generally the same time of the year, the water quality moving through the Pacheco Pumping Plant can create operation concerns.

San Felipe Division

The San Felipe Division provides CVP water to Santa Clara and San Benito counties, through conveyance facilities from San Luis Reservoir. Specific facilities include the Pacheco Tunnel and Conduit, the Hollister Conduit, San Justo Dam and Reservoir, Coyote Pumping Plant, and the Santa Clara Conduit. The Pajaro Valley, in southern Santa Cruz County, was originally authorized to receive irrigation water to reduce seawater intrusion caused by groundwater pumping. Although studies to reduce seawater intrusion and determine conveyance requirements have continued, facilities have not yet been constructed in the Pajaro Valley to receive the authorized water deliveries.

The Pacheco Tunnel and Pacheco Conduit convey water from the San Luis Reservoir to the upper ends of the Santa Clara and Hollister conduits. The Santa Clara Conduit conveys water primarily to urban service areas in the Santa Clara Valley. A portion of the water is delivered through the Santa Clara Conduit to local storage facilities, including Anderson Lake and Calero Reservoir. The Hollister Conduit conveys irrigation water to the Hollister service area.

Eastside Division

The Eastside Division of the CVP includes water storage facilities on the Stanislaus River (New Melones Dam, Reservoir, and Powerplant), Chowchilla River (Buchanan Dam and Eastman Lake), and Fresno River (Hidden Dam and Hensley Lake). These rivers drain the western slope of the Sierra Nevada and flow into the San Joaquin River. All of the dams and reservoirs in the Eastside Division were constructed by the COE. Upon completion in 1980, the operation of New Melones was assigned to Reclamation to provide flood control, satisfy water rights obligations, provide instream flows, maintain water quality conditions in the Stanislaus River and in the San Joaquin River at Vernalis, and provide deliveries to CVP contractors. Both Buchanan and Hidden dams are operated by the COE, and their operations are coordinated with CVP operations in the Friant Division to satisfy portions of the CVP contractual requirements on the Madera Canal.

The operating criteria for New Melones Reservoir are governed by water rights, instream fish and wildlife flow requirements, instream water quality, Delta water quality, CVP contracts, and flood control considerations. Water released from New Melones Dam and Powerplant is re-regulated at Tulloch Reservoir, an is either diverted further downstream at Goodwin Dam, or released from Goodwin Dam to the lower Stanislaus River. Flows in the lower Stanislaus River serve multiple purposes. These include provision of water for riparian water rights, instream fishery flow objectives, and instream DO. In addition water from the Stanislaus River enters the San Joaquin River, where it contributes to flow and helps to improve water quality conditions at Vernalis.

Requirements for New Melones Operations. D-1422, issued in 1973, provided the primary operational criteria for New Melones Reservoir, and permitted Reclamation to appropriate water from the Stanislaus River for irrigation and M&I uses. D-1422 requires that the operation of New Melones Reservoir include releases for existing water rights, fish and wildlife enhancement, and the maintenance of water quality conditions on the Stanislaus and San Joaquin rivers.

Water Rights Obligations. When Reclamation began operations of New Melones Reservoir in 1980, the obligations for releases to meet downstream water rights were defined in a 1972 Agreement and Stipulation among Reclamation, OID, and SSJID. The 1972 Agreement and Stipulation required that Reclamation release annual inflows to New Melones Reservoir of up to 654,000 acre-feet per year of water for diversion at Goodwin Dam by OID and SSJID, in recognition of their water rights. Actual historic diversions prior to 1972 varied considerably, depending upon hydrologic conditions. In addition to releases for diversion by OID and SSJID, water is released from New Melones Reservoir to satisfy riparian water rights totaling approximately 48,000 acre-feet annually downstream of Goodwin Dam.

In 1988, following a year of low inflow to New Melones Reservoir, the Agreement and Stipulation among Reclamation, OID, and SSJID was superseded by an agreement that provided for conservation storage by OID and SSJID. The new agreement required Reclamation to release inflows of up to 600,000 acre-feet each year to New Melones Reservoir for diversion at Goodwin Dam by OID and SSJID. In years when inflows to New Melones Reservoir are less than 600,000 acre-feet per year, Reclamation provides all inflows plus one-third the difference between the inflow for that year and 600,000 acre-feet per year. The 1988 Agreement and Stipulation created a conservation account, in which the difference between the entitled quantity and the actual quantity diverted by OID and SSJID in a year may be stored in New Melones Reservoir for use in subsequent years, provided that the CVP contractors have received their supply in that year.

Instream Flow Requirements. Under D-1422, Reclamation is required to release up to 98,000 acre-feet per year of water per year from New Melones Reservoir to the Stanislaus, on a distribution pattern to be specified each year by DFG, for fish and wildlife purposes. In 1987, an agreement between Reclamation and DFG provided for increased releases from New Melones to enhance fishery resources for an interim period, during which habitat requirements were to be better defined, and a study of chinook salmon fisheries on the Stanislaus River would be completed. During the study period, releases for instream flows would range from 98,300 to 302,000 acre-feet per year. The exact quantity to be released each year was to be determined based on storage, projected inflows, projected water supply and water quality demands, and target carryover storage. Because of dry hydrologic conditions in the 1987 to 1992 drought period, the ability to provide increased releases was limited. In 1993, the Service published the results of the study which recommended a minimum instream flow on the Stanislaus River of 155,700 acre-feet per year (Service, 1993).

Water Quality Requirements. D-1422 requires that water be released from New Melones to maintain DO concentrations in the Stanislaus River. The 1975 revision to the Water Quality Control Plan established a minimum DO concentration of 7 mg/l, as measured on the Stanislaus River near Ripon.

D-1422 specifies that New Melones Reservoir be operated to maintain an average monthly level of conductivity, commonly measured as TDS, on the San Joaquin River at Vernalis, as it enters the Delta. The original permit specifies an average monthly concentration of 500 parts per million (ppm) TDS for all months. Historically, releases have been made from New Melones Reservoir for this standard, but due to shortfalls in water supply, Reclamation has not always been successful in meeting this objective. In the past, when sufficient supplies were not available to meet the water quality standards for the entire year, the emphasis for use of the available water was during the irrigation season, generally from April through September.

As part of Order 95-06, the operational water quality objectives at Vernalis were modified to include the irrigation and non-irrigation season objectives contained in the May WQCP. The revised standards are average monthly concentrations of 0.7 micromhos/cm conductivity (approximately 455 ppm TDS) during the months of April through August, and 1 micromhos/cm (approximately 650 ppm TDS) during the months of September through March.

Hydropower Operations. New Melones Powerplant operations began in 1979. Power generation occurs when reservoir storage is above the minimum power pool of 300,000 acre-feet per year. Reservoir levels are maintained, if possible, to provide maximum energy generation. Tulloch Reservoir, owned by OID and SSJID, serves as an afterbay for the New Melones Powerplant.

Flood Control. New Melones Reservoir flood control operation is coordinated with the operation of Tulloch Reservoir. The flood control objective is to maintain flood flows at the Orange Blossom Bridge at less than 8,000 cfs. When possible, however, releases from New Melones Dam are maintained at levels that would not result in downstream flows in excess of 1,500 cfs, because of seepage and flooding problems associated with flows above this level. Of the 2.4 million acre-feet per year storage volume of New Melones Reservoir, up to 450,000 acre-feet per year is dedicated for flood control, and 10,000 acre-feet per year of Tulloch Reservoir storage is set aside for flood control. Based upon the flood control diagrams prepared by COE, part or all of the dedicated flood control storage may be used for conservation storage, depending on the time of year and the current flood hazard.

CVP Contracts. Reclamation has entered into water service contracts for the delivery of water from New Melones Reservoir, based on a 1980 hydrologic evaluation of the long-term availability of water in the Stanislaus River Basin. Based on this study, Reclamation entered into a long-term water service contract for up to 49,000 acre-feet per year of water annually based on a firm water supply, and two long-term water service contracts totaling 106,000 acre-feet per year, based on an interim water supply. Because diversion facilities were not yet fully operational and water supplies were not available during the 1987 to 1992 drought, no water was made available from the Stanislaus River for delivery to CVP contractors prior to 1992.

Friant Division

The Friant Division includes facilities to collect and convey water from the San Joaquin River to provide a supplemental water supply to areas along the east side of the southern San Joaquin River Basin and the Tulare Basin. The delivery of CVP water to this region augments groundwater and local surface water supplies in an area that has historically been subject to groundwater overdraft. The Friant Division is an integral part of the CVP, but is hydrologically independent and, therefore, operated separately from the northern and southern CVP systems. The water supply to this division was made available through an agreement with San Joaquin River water rights holders, who entered into exchange contracts with Reclamation for delivery of water through the Delta-Mendota Canal. Major facilities of the Friant Division include Friant Dam and Millerton Lake, the Madera Canal, and the Friant-Kern Canal.

The Friant Division was designed to support the conjunctive use of surface water and groundwater that has long been a major component in the management of water supplies in the San Joaquin River and Tulare Lake basins. To support the management of conjunctive use, a two-class system of water service contracts is employed. Class I contracts relate to "dependable supply," typically assigned users with limited access to good quality groundwater. Class II contracts are generally held by water users with access to good quality groundwater that can be used during periods of surface water deficiency. Groundwater recharge and recharge/exchange agreements are frequently employed in the management of Class II water supplies (Friant Water Users Authority, n.d.).

Friant Dam and Millerton Lake are located on the San Joaquin River below a drainage area of approximately 1,630 square miles. With a capacity of approximately 0.5 million acre-feet per year, Millerton Lake diverts water north to the Madera Canal and south to the Friant-Kern Canal, and makes releases to the San Joaquin River to satisfy riparian water rights between the dam and Gravelly Ford.

The Madera Canal extends north from Friant Dam and Millerton Lake to Ash Slough of the Chowchilla River in Madera County. A portion of the water supply to the Madera Canal service area is supplied through the integrated operation of Hidden Dam on the Fresno River and Buchanan Dam on the Chowchilla River, which are included in the Eastside Division of the CVP.

The Friant-Kern Canal extends south from Friant Dam and Millerton Lake in Fresno County to Kern County near Bakersfield. Individual irrigation districts integrate CVP water supplies with water supplies from the Kings, Kaweah, Tule, and Kern rivers and through exchange agreements between Friant-Kern and Cross Valley canal contractors.

The annual water supply from the Friant Division is determined independently from other divisions of the CVP. On February 15 of each year, Reclamation provides contractors with an estimate of the water supply for the coming contract year based on hydrological conditions, water supply storage in upstream reservoirs, and assumptions based on statistical analysis of historic records.

Of the 0.5 million acre-feet per year capacity of Millerton Lake, up to 390,000 acre-feet per year is reserved for flood control storage (COE, 1975). Based upon the flood control diagram prepared by COE, part or all of the dedicated flood control storage may be used for conservation storage, depending on the time of year and the current flood hazard. Flood control operations of Millerton Lake are influenced by the storage available in upstream reservoirs.

Flood control releases from Millerton Lake may be used to satisfy portions of deliveries to the Mendota Pool Contractors and the San Joaquin River Exchange Contractors on the San Joaquin River below Mendota Pool. Millerton Lake operations are coordinated with operations of the Delta-Mendota Canal in the Delta Division to use all available Millerton Lake flood control releases before additional water is delivered to Mendota Pool. During wet hydrologic periods, overflow from the Kings River may enter the San Joaquin River Basin at the Mendota Pool through the Fresno Slough. This water is also used to meet demands at Mendota Pool. Flood control releases from Millerton Lake that exceed the requirements of the San Joaquin River Exchange Contractors are diverted into the Chowchilla Bypass, until flows in the Chowchilla Bypass reaches its capacity of 6,500 cfs. This diversion of flow helps avoid flooding of agricultural lands located in the floodplain along the San Joaquin River below Gravelly Ford.

CENTRAL VALLEY PROJECT WATER USERS

As indicated in the previous discussion, the CVP was constructed after many of the major water rights in the Central Valley had been established. In the development of the CVP, Reclamation entered into long-term contracts with some of these existing water rights to establish water delivery requirements. Therefore, CVP is operated to satisfy downstream water rights, meet the obligations of the water rights contracts, and deliver project water to CVP water service contractors.

A water right is a legal entitlement that authorizes the diversion of water from a particular source for beneficial use. All water rights are limited to amounts reasonably necessary for the intended use and do not extend to wasteful or unreasonable use or means of diversion. It is not an ownership of water, but the opportunity to share in the responsible development and beneficial use of a public resource. There are two major kinds of water rights: riparian rights that generally come with land bordering a water source, and appropriative rights that are granted by the SWRCB or its predecessors. Prior to the development of the CVP, existing water rights had been established on the Sacramento, American, San Joaquin, and Stanislaus rivers.

Many of the CVP water rights originated from applications filed by the state in 1927 and 1938 to advance the California Water Plan. After the federal government was authorized to build the CVP, those water rights were transferred to Reclamation; Reclamation made applications for the additional water rights needed for the CVP.

In granting water rights, the SWRCB sets certain conditions to protect prior water rights, fish and wildlife needs, and other prerequisites it deems in the public interest. Permits for CVP facilities include conditions requiring minimum flow below dams, and specify periods of the year when water may be directly diverted and periods when water may be stored at CVP facilities.

SACRAMENTO RIVER WATER RIGHTS CONTRACTORS

Sacramento River Water Rights Contractors are contractors who for the most part claim water rights on the Sacramento River. With the control of the Sacramento River by Shasta Dam, these water right claimants entered into contracts with Reclamation. Most of the agreements established a quantity of water the contractor is allowed to divert from April through October without charge and provided a supplemental CVP supply allocated by Reclamation.

SAN JOAQUIN RIVER EXCHANGE CONTRACTORS

San Joaquin River Exchange Contractors are CVP contractors who receive Project water from the Delta at Mendota Pool. Under the Exchange Contracts, the parties agreed to not exercise their San Joaquin River water rights in exchange for a substitute Project water supply from the Delta. These exchanges allow for water to be diverted from the San Joaquin River at Friant Dam under the water rights of the United States for storage at Millerton.

CVP WATER SERVICE CONTRACTS

Before construction of the CVP, many irrigators on the west side of the Sacramento Valley, on the east and west sides of the San Joaquin Valley, and in the Santa Clara Valley relied primarily on groundwater. With the completion of CVP facilities in these areas, the irrigators signed agreements with Reclamation for the delivery of CVP water as a supplemental supply. Several cities also have similar contracts.

CVP water service contracts are between the United States and individual water users or districts and provide for an allocated supply of CVP water to be applied for beneficial use. In addition to CVP water supply, a water service contract can include a supply of water that recognizes a previous water right. The purposes of a water service contract are to stipulate provisions under which a water supply is provided, to produce revenues sufficient to recover an appropriate share of capital investment, and to pay the annual operations and maintenance costs of the project.

Typical water service contracts include provisions that establish the following:

- the maximum quantity of water to be made available
- the types of water delivered, such a irrigation or M&I
- water shortage criteria
- acreage limitations
- water conservation requirements
- water and air pollution control regulatory requirements
- rate setting

Three types of water service contracts are used in the CVP as follows:

- Long-term contracts which have a term of more than 10 years. The Acts of July 2, 1956, and June 21, 1963, provide for renewal of these contracts at the request of the contractor.
- Short-term contracts which have a term of more than 5 but less than 10 years. Reclamation law does not provide for renewal of these contracts.

- Temporary contracts which have a term not to exceed 5 years. As with short-term contracts, these are no provisions within reclamation law for renewing temporary contracts.

Only long-term water service contracts are included in the PEIS analyses.

Some of the wildlife refuges in the Sacramento and San Joaquin valleys have long-term water service contracts for the delivery of water from the CVP. Annual deliveries under these contracts are subject to the same criteria used to determine deliveries to the CVP agricultural water service contractors.

Friant Division Contractors

The water supply that is developed by the Friant Division is made available in part through an exchange agreement with the Exchange Contractors who hold water rights on the San Joaquin River. Water from Millerton Lake is diverted north through the Madera Canal, and south through the Friant-Kern Canal. The Friant Division was designed to support the conjunctive use of surface water and groundwater that has long been a major component in the management of water supplies in the San Joaquin River and Tulare Lake basins. To support the management of conjunctive use, a two-class system of water service contracts is employed in the Friant Division.

Class I contracts are typically assigned to M&I users and agricultural districts with limited access to good quality groundwater. Class I water is available in most years and is considered to be a dependable supply.

Class II water is that supply available in addition to Class I water. Because of uncertainty in its annual availability and time of occurrence, it is not considered a dependable supply. Class II contracts are generally held by M&I and agricultural water users that have access to good quality groundwater that can be used during periods of surface water deficiency. Groundwater recharge and recharge/exchange agreements are frequently used in the management of Class II water supplies. Class II water is usually available in the full contract amount during wet years only. Class II water is taken on an as-available basis. On average only about 50 percent of the total contracted supply is available to contractors.

Cross Valley Canal Contractors

The Cross Valley Canal contractors are water users on the Friant-Kern Canal who receive water via an exchange made possible by DWR wheeling water through the SWP to the Cross Valley Canal. DWR diverts water for Reclamation from the Delta at the Banks Pumping Plant, through the California Aqueduct, and to the SWP's portion of San Luis Reservoir. From San Luis reservoir, the water is conveyed via the San Luis Canal to the Cross Valley Canal turnout in Kern County, and delivered to Arvin Edison Water Service District. Arvin Edison Water Service District takes delivery of the Delta water, then "exchanges" water under contract with Reclamation from the Friant Division with other Reclamation contractors on the Friant-Kern Canal. The Cross Valley Canal contract is for an annual delivery of 128,000 acre-feet per year of water, depending on availability.

CRITERIA FOR WATER DELIVERIES TO CVP CONTRACTORS

The criteria for deliveries to CVP contractors consider available water supplies and superior obligations on the use of the available water. Decision-making criteria are similar within various units and divisions of the CVP. The criteria applicable to CVP contractors served by the North System (Trinity, Shasta, Sacramento River, and American River divisions) and the South System (Delta, West San Joaquin, and San Felipe divisions) are similar. The criteria applied to establish water delivery deficiencies in the Friant Division are somewhat different because this division is operated to provide water supplies for conjunctive use. In addition, the criteria for operations of New Melones Reservoir, and contract deliveries on the Stanislaus River, are affected by conditions unique to the Stanislaus River watershed.

Shasta Criteria

Shortage conditions for providing water to the Sacramento River Water Rights Contractors, the San Joaquin River Exchange Contractors, and the Mendota Pool Contractors are based on the "Shasta Criteria". The Shasta Criteria are used to establish when a water year is considered critical, based on inflow to Shasta Lake.

As defined by the Shasta Criteria, when inflows to Shasta Lake fall below specified thresholds, water year is critical, and water deliveries to the contractors may be reduced. A critical year is defined as one in which the full natural inflow to Shasta Lake for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year) is equal to or less than 3.2 million acre-feet per year. This is considered a single-year deficit. A critical year is also as one in which the accumulated difference (deficiency) between 4 million acre-feet per year and the full natural inflow to Shasta Lake for successive previous years, plus the forecasted deficiency for the current water year, exceeds 800,000 acre-feet per year.

Criteria for Deliveries to CVP Contractors in the North and South Systems

The criteria used to establish annual delivery amounts to CVP contractors served by the Sacramento River, American River, Delta, West San Joaquin, and San Felipe divisions is uniform. The following discussion does not apply to CVP contractors in the Friant and East Side Divisions. Criteria for annual water delivery quantities in these divisions are dependent on hydrologic and operational conditions unique to the individual divisions and are discussed in a subsequent section of this chapter.

Except in times of water shortages, the CVP makes available the amounts of water specified in the terms of its contracts in the CVP North and South systems. Water availability for delivery to the Sacramento River Water Rights Contractors is based on the Shasta Criteria which, as described above, reduces deliveries to 75 percent of the contract amount during critical years. Water availability for delivery to San Joaquin River Exchange Contractors and to Medota Pool Contractors is approximately based on the Shasta Criteria. Water availability for delivery to CVP water service contractors during periods of insufficient water supply is determined based on a combination of operational objectives, hydrologic conditions, and reservoir storage conditions. Reclamation is required to allocate shortages equally among water service contractors within the same service area, as individual contracts and CVP operational capabilities permit. In practice, agricultural contractors and some M&I contractors have received equal reductions in allocations during years of low water availability. Some M&I contracts prohibit the imposition of shortages until allocations to agricultural contractors are reduced by at least 25 percent.

The decision-making process for allocating the water supply available to CVP contractors involves comparing the forecasted conditions of reservoir storage and allocated water supply for the current year with the risks of potential impacts in the following water year or years. No formal rule or risk analysis exists upon which to make this decision. The process used during the recent years of drought conditions forms a basis for the current allocation decision process.

Soon after the beginning of the water year, the upcoming year's operations are forecasted on the basis of a range of assumed hydrologic and operations conditions. Generally, an initial array of operations forecasts is presented to Reclamation managers in December, updated by additional arrays prepared by January. These early forecasts may or may not include assumed water supply shortages, depending on reservoir storage existing at the time and the severity of the assumed hydrology of each forecast. The number of early forecasts developed may vary depending on the scope and complexity of the possible responses of the CVP to the range of operations conditions being examined. Because of widely varying weather conditions from year to year, no reliable forecasts of seasonal runoff are available before February.

Operations forecasts prepared before February are based on current storage conditions and an array of scenarios covering the reasonably expected range of runoff for the remainder of the season. These early operations forecasts provide direction for forecasting and a method of assessing current and future conditions and preliminary implications of alternative decisions. The operations forecasts provide monthly information on water allocations, reservoir storage, releases, electrical generation and capacity, Delta exports and inflows, and Delta outflow requirements. By developing an array of possible conditions, CVP operators and managers can evaluate potential problems in advance of the first official water allocations announcement, which is made by Reclamation on February 15.

The February 15 forecasts of runoff and CVP operations are used to develop the initial water allocations announcement for the current year. Agricultural contractors need to know what their minimal water supply will be as early as possible to support timely decisions regarding crop types, delivery schedules, water transfer possibilities, and other related issues. Water rights and exchange contracts require notification of shortages not later than February 15; no additional shortages may be imposed after that date. Other water service contractors generally have no such provisions in their contracts. Because of the uncertainty regarding the total available water supply, the February forecast of runoff and CVP operations must be based on a conservative prediction of spring and summer runoff. This approach minimizes the likelihood that the projected allocation to water service contractors would need to be further reduced in adverse hydrologic conditions. In some years, the allocations to CVP water service contractors have increased after the February announcement when improved hydrologic conditions increased the projections of runoff and reservoir carryover storage conditions. Similarly, in years initially categorized as critical under the Shasta Criteria, allocations to water rights and exchange contractors have been restored when the forecasted natural inflow to Lake Shasta increases to a non-critical level.

The February 15 water allocation decision reflects assessments of both total CVP reservoir storage upstream of the Delta and individual CVP reservoir storage. Because the integrated CVP operations focus on requirements in the Delta, the total storage available to meet these requirements is one measurement of water supply. Further, because the Delta requirements include limitations on CVP export operations, the forecasting process can be iterative to achieve the balance between storage and water delivery levels. Storage levels in individual reservoirs are subject not only to Delta water requirements but also to the geographical distribution of precipitation and runoff during the year, local demands, and minimum streamflow needs below each reservoir. Updated monthly operations forecasts, after the initial February 15 forecast, are used to identify both total and individual reservoir storage needs and impacts.

Criteria for Deliveries to CVP Contractors in the Friant Division

The determination of annual water supply from the Friant Division is done independently from other divisions of the CVP. On February 15 of each year, Reclamation provides Friant Service Area contractors with an estimate of the water supply for the coming contract year based on hydrological conditions, water supply storage in upstream reservoirs, and assumptions based on statistical analysis of historic records. This estimate is revised monthly throughout the contract year.

Criteria for Deliveries to CVP Contractors in the Eastside Division

Historically, Reclamation has had difficulty meeting all of the operational obligations on New Melones Reservoir. This difficulty became apparent during the period of 1987-1992 when New Melones Reservoir was drawn down to approximately 80,000 acre-feet per year in 1992. Numerous unanticipated operational factors influenced the drawdown of New Melones during this period. These include the severity of drought conditions from 1989 through 1992, the effect of water quality of return flows into the San Joaquin River on the ability to attain the water quality objectives, and low instream flows on the Merced and Tuolumne rivers. During the drought period, Stanislaus River stakeholder meetings were convened to coordinate operational objectives to manage the limited water supplies available.

STATE WATER PROJECT WATER USERS AND OPERATIONS

The SWP includes facilities to capture and store water north of the Delta, on the Feather River, and to deliver water to service areas in the Feather River Basin, the San Francisco Bay area, the San Joaquin Valley, the Tulare Basin, and Southern California. The major facilities of the SWP, as well as the extent of the SWP service area, are shown in Figure II-17.

The SWP operates four reservoirs in the Feather River Basin. Three relatively small reservoirs in the upper Feather River Basin in Plumas County include Lake Davis, Frenchman Lake, and Antelope Lake. These reservoirs are operated for recreational, fish and wildlife, and local water

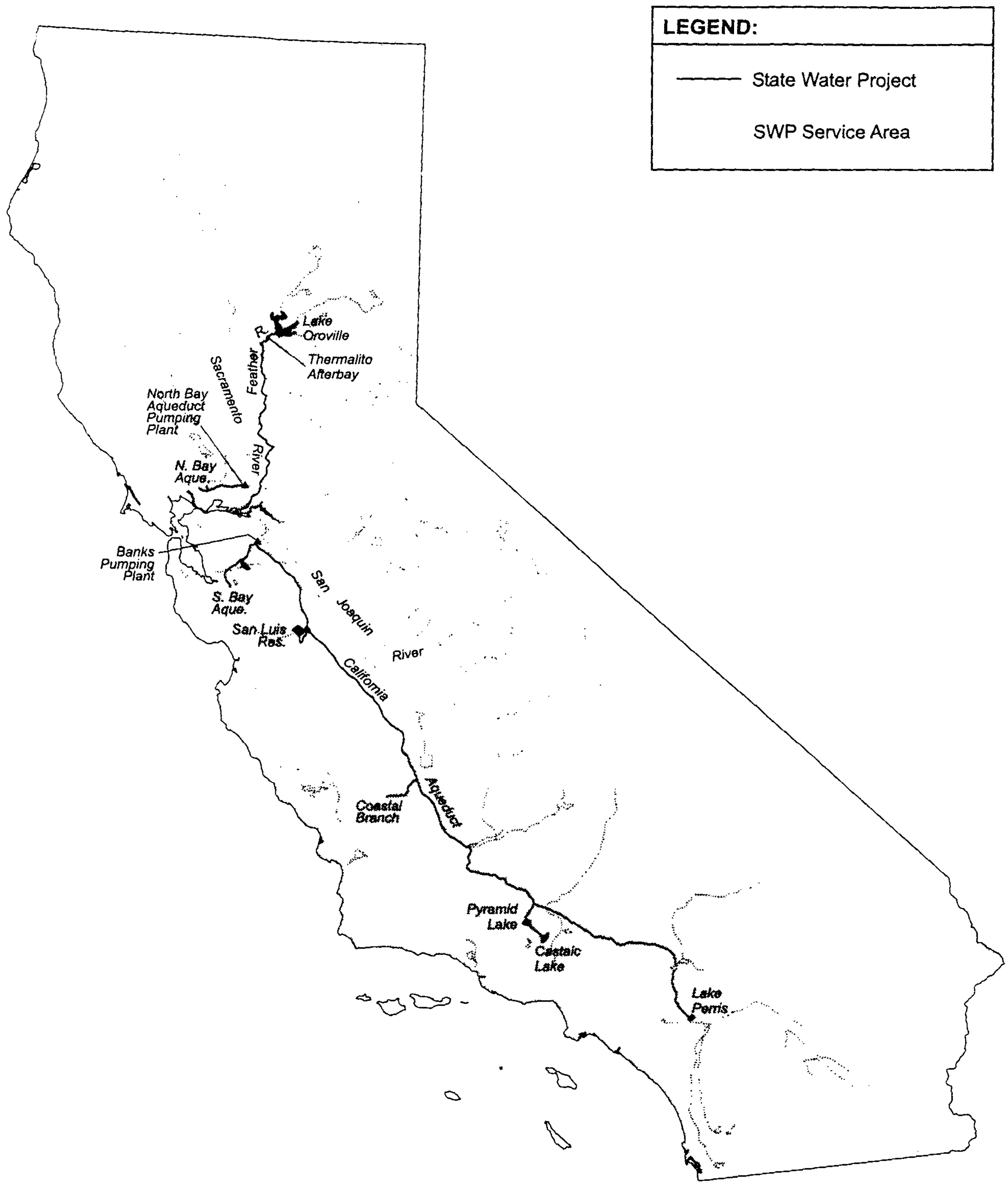


FIGURE II-17

STATE WATER PROJECT AND SERVICE AREAS

supply purposes. Farther downstream in the foothills of the Sierra Nevada is the multi-purpose Lake Oroville, the second largest reservoir in California, with a storage capacity of approximately 3.5 million acre-feet per year. Lake Oroville is used to conserve and regulate the flows of the Feather River for subsequent release to the Delta, where they can be diverted by various facilities of the SWP for delivery to contractors, or to provide salinity control against the intrusion of saline water from the ocean. Hydroelectric power production at Oroville represents a major source of revenue for the SWP. Oroville Dam and Lake Oroville also provide flood control for the protection of downstream communities and developed lands. Releases from Oroville Dam are re-regulated by the Thermalito Diversion Dam and Reservoir, completed in 1967, with a storage capacity of 13,000 acre-feet per year. This facility diverts the water released from Lake Oroville from the Feather River into Thermalito Forebay for use in power generation at the Thermalito Powerplant. Releases from the powerplant flow into the Thermalito Afterbay, for regulation of releases to the Feather River.

The North Bay Aqueduct diverts water from the north Delta near Cache Slough, which began operation of initial facilities in 1968. Construction of final facilities was completed in the mid-1980s. The North Bay Aqueduct which extends from Barker Slough to the Napa Turnout Reservoir in southern Napa County, conveys water for SWP entitlements and provides conveyance capacity for the City of Vallejo. The aqueduct serves agricultural and municipal areas in Napa and Solano counties, including Solano Irrigation District and the cities of Fairfield and Vallejo.

In the southern portion of the Delta, the Banks Delta Pumping Plant lifts water into the California Aqueduct from the Clifton Court Forebay. Clifton Court Forebay serves as a regulating reservoir for the pumping plant, allowing much of the pumping to occur at night when energy costs are lower. It also allows diversion from the Delta to be varied to minimize salinity intrusion. The John E. Skinner Delta Fish Protective Facility removes migrating fish drawn from the Delta with the pumping plant inflow.

The California Aqueduct is the state's largest and longest water conveyance system, beginning at the Banks Pumping Plant in the southwestern portion of the Delta and extending to Lake Perris south of Riverside, in Southern California. Bethany Reservoir, at the head of the California Aqueduct, provides an afterbay for discharges from the Banks Delta pumps and serves as a regulating reservoir for the California and South Bay aqueducts. The South Bay Aqueduct delivers water to urban and agricultural areas in the Santa Clara and Livermore-Amador valleys. Water in the California Aqueduct flows to O'Neill Forebay, which marks the beginning of the federal-state joint-use facilities. At the O'Neill Forebay, part of the flow is lifted through the William R. Giannelli Pumping-Generating Plant to the joint CVP/SWP San Luis Reservoir for offstream storage. From O'Neill Forebay, the joint-use portion of the aqueduct extends south to the Kettleman City area. From the Dos Amigos Pumping Plant near Kettleman City, the water flows to the southern end of the San Joaquin Valley, where it is pumped over the Tehachapi Mountains to the South Coast Region by the Edmonston Pumping Plant.

The initial facilities in the Coastal Branch of the California Aqueduct consist of a 15-mile-long canal and two pumping plants, constructed as part of the SWP. These initial facilities extend from the California Aqueduct in southwestern Kings County to western Kern County near Devils Den.

Construction of facilities to complete the Coastal Aqueduct is now underway. The Coastal Aqueduct is being extended to the Santa Barbara area with the addition of an 87-mile pipeline. Several terminal storage reservoirs have been constructed in the South Coast Region, including Silverwood Lake, Lake Perris, Pyramid Lake, and Castaic Lake. These lakes are operated, independent of operations within the Central Valley, for the purposes of deliveries, flow regulation, and emergency storage. Power is generated at Castaic Lake.

STATE WATER PROJECT WATER USERS

Currently, the SWP has contracted a total of 4.23 million acre-feet per year of water for delivery in the San Joaquin River Region, the Central Coast Region, and the San Francisco and South Coast regions. Of this amount, about 2.5 million acre-feet per year is designated for the Southern California Transfer Area, nearly 1.36 million acre-feet per year to the San Joaquin Valley, and the remaining 0.37 million acre-feet per year to the San Francisco Bay Region, the Central Coast Region, and the Feather River area. Generally, deliveries to the San Joaquin River Region from the SWP have been near full contract amounts since about 1980, except during very wet years when the total contract amount was not required, and during deficient supply years. Deliveries to the South Coast Region have been at approximately 60 percent of the contract entitlement (DWR, 1994).

SWP Contract Entitlements

Contracts executed in the early 1960s established the maximum annual water amount (entitlement) that each long-term contractor may request from the SWP. The annual quantities, specified on Table A in DWR Bulletin 132 (Operation of the State Water Project annual reports) reflect each contractor's projected annual water needs at the time the contracts were signed. Every September, each contractor must submit a request to the DWR for water delivery for the next 5 years. (This request cannot exceed the contractor's Table A allocation.) These 5-year projections form the basis for SWP planning and operation studies in the upcoming year.

The SWP delivers water to agricultural and M&I water contractors based on criteria established in the Monterey Agreement, which provides for the application of equal deficiency levels to all contractors.

Allocation of water supplies for a given year is based on four variables:

- forecast water supplies based on the Sacramento River Index (the Sacramento River Index is the sum of measured runoff at four locations: Sacramento River near Red Bluff, Feather River inflow to Lake Oroville, Yuba River at Smartville, and American River inflow to Folsom Lake);

- amount of carryover storage in Oroville and San Luis reservoirs;

- projected requirement for end-of-year carryover storage; and

- SWP system delivery capability.

These criteria ensure that sufficient water is carried over in storage to protect Delta water quality the next year, to meet fishery requirements, and to provide an emergency reserve. Beginning in December each year, initial allocations of entitlement deliveries are determined based on the four criteria. Allocations are updated monthly until May, and more often if significant storms result in an increase in the Sacramento River Index.

Following is a chronology of the SWP water delivery allocation process.

- December. Initial allocations are made, based on operation studies using the four criteria and an assumed historical 90 percent accedence water supply. Accedence refers to the probability that a particular value will exceed a specified magnitude; for example, 90 percent accedence means the water supply will be exceeded 90 percent of the time.

- January and February. Allocations will not be reduced, even if water supply forecasts and operation studies indicate the initial allocation may be too high. Allocations may be increased if the water supply forecast (99 percent accedence) and operation studies show delivery capability to be greater than forecast the month before.

- March. Allocations will be reduced if the supply is less than forecast in December. Allocations can be increased based on forecasted 99 percent accedence water supplies.
- April and May. Allocations will not be reduced further unless operational storage and forecast runoff (99 percent accedence) indicate carryover conservation storage will fall below targeted minimums. Increases in water delivery allocations can be made based on improved 99 percent accedence forecasts and supportive operational studies. Final allocations are based on the May water supply forecast.

Feather River Settlement Contractors

The Feather River Settlement Contractors are water users who held riparian and senior appropriative rights on the Feather River. As the SWP was built, the state entered into contractual agreements with these existing water rights holders (e.g., water rights settlements). Most of these agreements established the quantity of water the contractor is permitted to divert under independent senior water rights on a monthly basis and outlined supplemental SWP supply allocated by the state. Contract shortages are applied based on hydrologic conditions and storage in Lake Oroville.

STATE WATER PROJECT OPERATIONS

The operation of the SWP is affected by D-1485, instream flow requirements on the Feather River, and pumping limitations at the Banks Pumping Plant. A discussion of D-1485 is provided in the description of operating criteria that affect the CVP and is not repeated in this section. A discussion of the remaining operational requirements of the SWP follows.

Feather River Minimum Instream Flows

Feather River minimum fish flow requirements are maintained per the August 26, 1983, agreement between DWR and DFG. In normal years these minimum flows are 1,700 cfs from October through March and 1,000 cfs from April through September, with lower minimum flows allowed in dry and critical dry years. Additionally, the maximum flow restriction of 2,500 cfs for October and November is maintained per the agreement criteria.

Banks Pumping Plants Limits

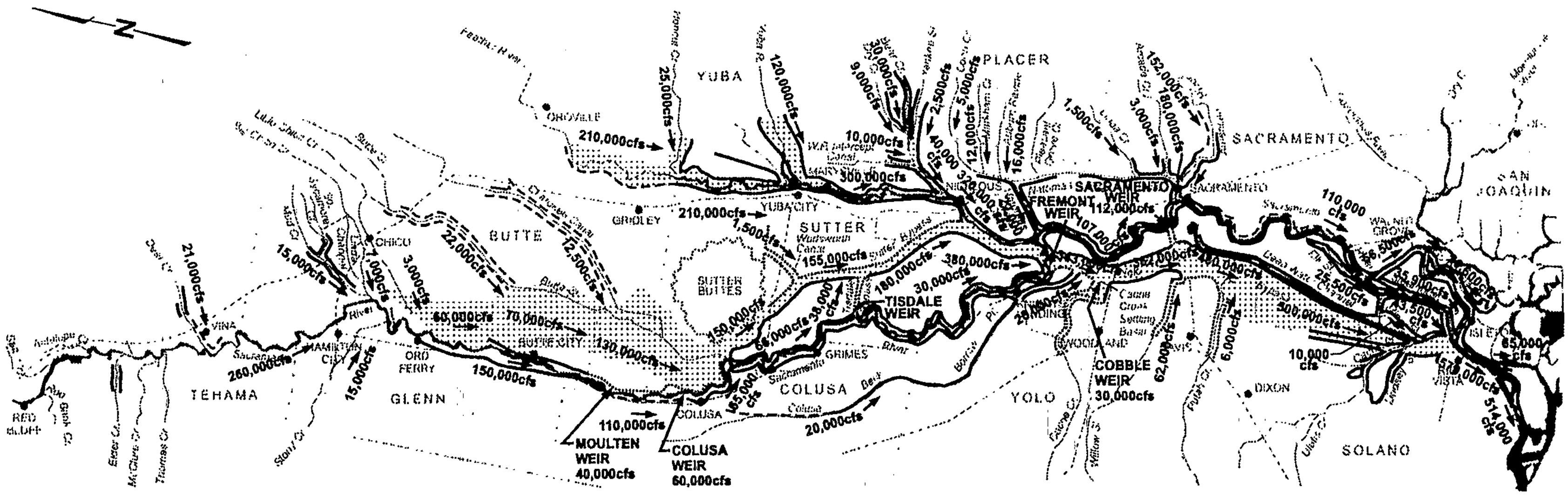
The Banks Pumping Plant is operated to meet demands south of the Delta. In October, November, April, August, and September, pumping capacity at the Banks Pumping Plant is 6,680 cfs. Between December 15 and March 15, pumping may be augmented above 6,680 cfs, depending upon flow in San Joaquin River at Vernalis per the COE's October 13, 1981, Public Notice criteria. In December and March, the augmented flows are 7,590 cfs, and in January and February the augmented flows are 8,500 cfs. A maximum of 8,500 cfs is assumed based on hydraulic constraints surrounding the pumps. Improvements south of the Delta that would allow the full 11-pump capacity of 10,300 cfs to be realized are assumed not to be in place. In May and June, D-1485 criteria for stripped bass survival reduces pumping capacity to 3,000 cfs. Additionally SWP pumping is limited to 2,000 cfs in any May or June in which storage withdrawals from Oroville Reservoir were required (per the January 5, 1987, Interim Agreement between DWR and DFG). In July, D-1485 criteria for striped bass survival reduces pumping capacity to 4,600 cfs.

FLOOD CONTROL IN THE CENTRAL VALLEY

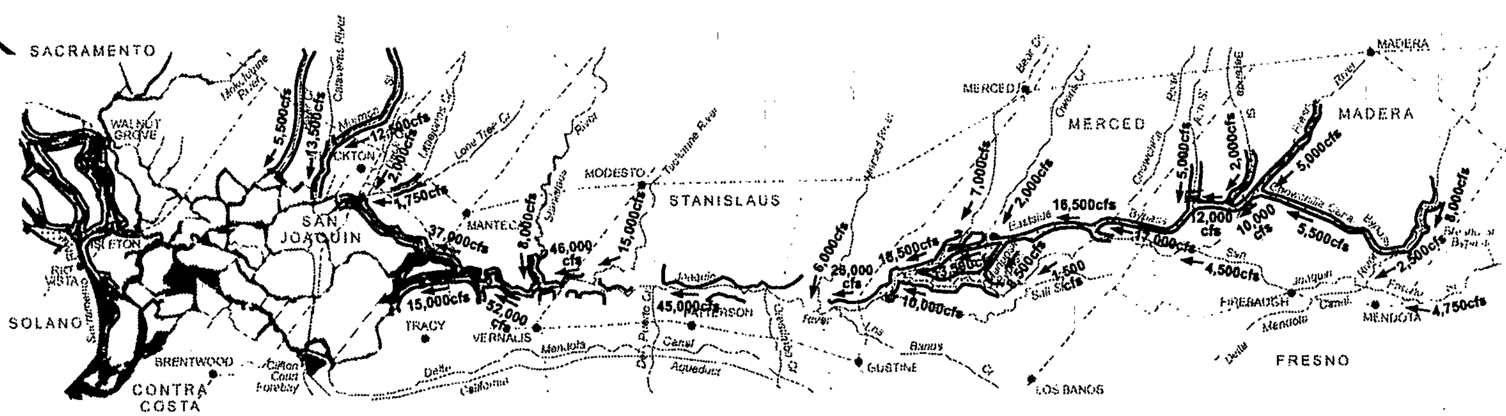
The COE is responsible for flood control in the State of California. In this capacity, the COE has developed operations and storage criteria for several reservoirs permitted for flood protection. Most of the water supply reservoirs potentially affected by CVPIA actions are permitted for flood protection, and are operated in accordance with flood control rules. Flood control operational criteria for CVP reservoirs is discussed in a previous section of this chapter.

In addition to reservoir storage criteria, the COE has determined flow capacities for various locations along major rivers and drainage areas in the Central Valley. Figure II-18 shows the flood channel design flow capacities for various locations along rivers in the Sacramento and San Joaquin valleys. Controlled releases of stored water from upstream facilities are limited to quantities that would not cause these design capacities to be exceeded. Historically, flood channel capacities have been exceeded at several of the shown locations, as a result of uncontrolled releases from upstream facilities and local runoff.

In addition to reservoirs, other flood control facilities in the Central Valley include the Sutter and Yolo bypasses, on the Sacramento River system and the Chowchilla and Eastside bypasses on the San Joaquin River system. These facilities provide bypass routing of excessive flows, and provide flood protection to downstream locations. Flows into these flood control facilities are regulated by weirs and gates, which are operated either by COE or local reclamation or levee districts.



SACRAMENTO RIVER AND TRIBUTARIES



SAN JOAQUIN RIVER AND TRIBUTARIES

- - - - Project Levees Maintained By Department of Water Resources, Sec. 12878 to Sec. 12878.45 of the Water Code.

.... Project Levees Maintained By Department of Water Resources, Sec. 8361 of the Water Code.

—— Project Levees Maintained By Reclamation, Levee, and Drainage Districts and Municipalities.

20,000cfs → Flood Channel Design Flows.

Source: CWR, 1985.

FIGURE II-18

FLOOD CHANNEL DESIGN FLOWS

CHAPTER III

ENVIRONMENTAL CONSEQUENCES

Chapter III

ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter summarizes potential changes to the operation of CVP facilities, river flow regimes, and CVP water supply deliveries that would result from the implementation of the alternatives considered in the Draft PEIS. The Draft PEIS alternatives include a range of component CVPIA actions that would affect facility and river operations, as well as the availability of water supplies to CVP water users. These component CVPIA actions include the dedication of CVP water supplies toward meeting the target flows, the delivery of firm Level 2 refuge water supplies, and releases from Lewiston Dam to provide increased instream Trinity River flows. Additional actions include the retirement of land pursuant to the San Joaquin Valley Drainage Plan, and the acquisition of water from willing sellers for delivery to wildlife refuges, increased instream flows, and increased Delta outflow.

The chapter begins with a brief discussion of the impact assessment methodology used for analysis of the Draft PEIS alternatives, followed by a description of the assumptions and operational criteria used in the No-Action Alternative, which serves as the base condition for the Draft PEIS impact analysis. For each alternative, the objectives and CVPIA actions included in the alternative are presented along with model simulation results showing the re-operation of CVP facilities, SWP facilities, and local water supply project facilities towards accomplishing the goals of the alternative.

The analysis focuses primarily on the operation of surface water supply facilities, and describes changes in reservoir storage conditions, reservoir releases, resulting downstream river flows, deliveries of surface water pursuant to CVP and SWP contracts, and water acquisition quantities.

IMPACT ASSESSMENT METHODOLOGY

The impact assessment methodology used to support the analysis presented in this chapter is based on the use of surface water, groundwater, and agricultural economics computer model analyses. Model simulations were conducted at a planning level, in accordance with the programmatic nature of the overall Draft PEIS analysis. The Project Simulation Model (PROSIM) and the San Joaquin Area Simulation Model (SANJASM) were used to evaluate the potential to re-operate system reservoirs towards meeting CVPIA objectives, and assess the resulting impacts to CVP water supply deliveries.

The model simulations for the Draft PEIS analyses were conducted using the historical hydrology for the period 1922 through 1990, adjusted to be representative of a projected 2020 level of development. The projected land-use conditions were based on information developed for DWR Bulletin 160-93 (DWR, 1993) and are assumed to be constant over the simulation period. The historical hydrology for the 1922 through 1990 period is considered to be representative of the range of hydrologic conditions that may be expected under future CVP operations.

The models use a monthly time step and general operations criteria representative of CVP operations. The simulations do not take into account daily or weekly changes in operations, river travel time, or fluctuations in natural hydrology. A discussion of the specific approach, model modifications, and data development required to apply these analytical tools to the analysis of the alternatives in the Draft PEIS is provided in the PROSIM and SANJASM Methodology/Modeling Technical Appendices.

Subsequent to the completion of the surface water modeling conducted for the Draft PEIS, Reclamation and the Service have discovered an inconsistency in the PROSIM input hydrology that may cause the model to over estimate the potential flexibility of CVP operations. As a result, current PROSIM simulations may under estimate the use of CVP storage and conversely over estimate water deliveries in some critical dry years. This inconsistency affects all of the Draft PEIS simulations, including the No-Action Alternative, and has a minimal impact on the relative differences between the simulations. Therefore, there is little affect on the comparison of surface water issues in the Draft PEIS, due to the general programmatic nature of the Draft PEIS analyses and the comparative use of the PROSIM simulation results. However, this reduction in operational flexibility in the No-Action Alternative may make incremental reductions in water availability in the other alternatives more difficult to accommodate operationally.

NO-ACTION ALTERNATIVE

The No-Action Alternative provides a base condition for comparison of Draft PEIS alternatives analyses, and represents assumed future conditions at a projected 2022 level of development without implementation of CVPIA. As described in Chapter II of the Draft PEIS, the No-Action Alternative assumes that CVP facilities would be operated in accordance with operating rules and criteria that were in effect or being developed as of October 1992 when the CVPIA was adopted.

The No-Action Alternative assumes the continued implementation of the Bay-Delta Plan Accord and WR-95-01 because the process to develop the new Delta water quality standards was being implemented at the time CVPIA was enacted. Similarly, the No-Action Alternative includes the 1993 Winter-Run Chinook Salmon Biological Opinion as amended in 1995 by NMFS, because Reclamation had begun to operate to preliminary provisions of the 1993 biological opinion in October 1992. As described in the Affected Environment, requirements of the 1995 Delta Smelt Biological Opinion are fulfilled through meeting the operations requirements of the Bay-Delta Plan Accord, WR-95-01, and 1995 amendments to the Winter-Run Chinook Salmon Biological Opinion. On the Stanislaus River, it is assumed that the interim drought management actions implemented during the drought period from 1987 through 1992 do not constitute a long-term operational approach, and therefore could not be anticipated to represent operational conditions in the year 2022. Descriptions of the Bay-Delta Water Quality Control Plan, the Winter Run Biological Opinion, and the operations of New Melones Reservoir are provided in the description of the No-Action Alternative in Chapter II of the Draft PEIS.

For the purposes of the Draft PEIS No-Action Alternative, it is assumed that the COA, as described in Chapter II, would remain in place in the year 2022. The COA is the mechanism by which the CVP and SWP coordinate operations to meet Delta standards as defined by SWRCB Water Quality Control Plans. The current COA was developed based on the SWRCB D-1485 standards. Additional assumptions were required to adapt the COA to criteria included in the May 1995 Draft Water Quality Control Plan. In the analysis of Draft PEIS alternatives, it is assumed that total CVP and SWP exports would be reduced on an equal basis to meet monthly export/inflow ratios, and export limitations from April 15 through May 15. These assumptions do not necessarily reflect revisions to the COA that may occur at a future time. A detailed description of the assumptions regarding the COA and May 1995 Draft Water Quality Control Plan in the Draft PEIS analyses is presented in the PROSIM Methodology/Modeling Technical Appendix.

ALTERNATIVE 1

DESCRIPTION OF ALTERNATIVE

Water management provisions in Alternative 1 were developed to utilize two of the tools provided by CVPIA, 3406(b)(1)(B) Re-operation and 3406(b)(2) Water Management, toward meeting the target flows for chinook salmon and steelhead trout in the CVP-controlled streams. In the Draft PEIS, the term "(b)(2) Water Management" is used to indicate the integrated use of 3406(b)(1)(B) Re-operation and 3406(b)(2) Water Management. As described in Chapter II of the Draft PEIS, Alternative 1 also includes the use of CVP water to provide firm Level 2 water supplies to refuges, and the preliminary Trinity River instream fishery flow pattern developed by the Service for the Draft PEIS.

Under Alternative 1, the CVP would be operated in an attempt to increase September end-of-month storage in Shasta and Folsom lakes in order to provide increased reservoir releases in the fall into the Sacramento and American rivers as compared to the No-Action Alternative. Increased reservoir releases would also be made from Whiskeytown Lake to increase Clear Creek minimum flows year round, and from New Melones Reservoir to provide higher flows on the Stanislaus River to attempt to meet flow targets. Increased releases from Clair Engle Lake, to meet Trinity River instream fishery flows, would release the spring and summer diversions to the Sacramento River.

The combined implementation of (b)(2) Water Management, the increase to firm Level 2 refuge water supply deliveries, and the modified Trinity River pattern would affect CVP operations and would result in changes in deliveries to water service contractors. A brief description of each component of Alternative 1 is provided below.

PEIS (b)(2) Water Management

The goal of the PEIS (b)(2) Water Management analysis was to develop a simplified strategy for use in the Draft PEIS alternatives. The Draft PEIS analysis was purposely limited to a planning level evaluation, due to the many uncertainties associated with the prioritization, allocation, and accounting of (b)(2) water. The approach consisted of development of preliminary prescriptions designed to attempt to meet the target flows developed by the Service and presented in Attachment G-4 of the Draft PEIS. This simplified analysis was developed for the purposes of the Draft PEIS only. The formal Water Management Plan (WMP) process, involving Reclamation and the Service, will provide detailed evaluation of the use of (b)(2) water for incorporation into CVP operating prescriptions for Reclamation's Operations and Criteria Plan. A description of the development of the PEIS (b)(2) Water Management and associated assumptions is presented in Attachment G-2 of the Draft PEIS.

Firm Level 2 Refuge Water Supplies

Alternative 1 includes delivery of firm CVP water supply to 19 wildlife refuges. Diversion quantities would include additional water to provide for conveyance losses, which previously had often been provided by users that conveyed water to the refuges. The annual firm Level 2 refuge water supply amounts are presented in Table III-1.

Firm Level 2 annual refuge water supplies provide an additional 245,000 acre-feet per year above the Level 2 refuge water supplies delivered in the No-Action Alternative simulation. These increased refuge water supplies are subject to shortage criteria based on the Shasta Index, which imposes a maximum shortage of 25 percent. In wet, above normal, and some below normal water year types, there is often enough water to deliver the increased refuge water supplies without affecting deliveries to CVP Water Service Contractors. In dry and critical dry year types, increased deliveries to refuges may result in reduced deliveries to CVP Water Service Contractors.

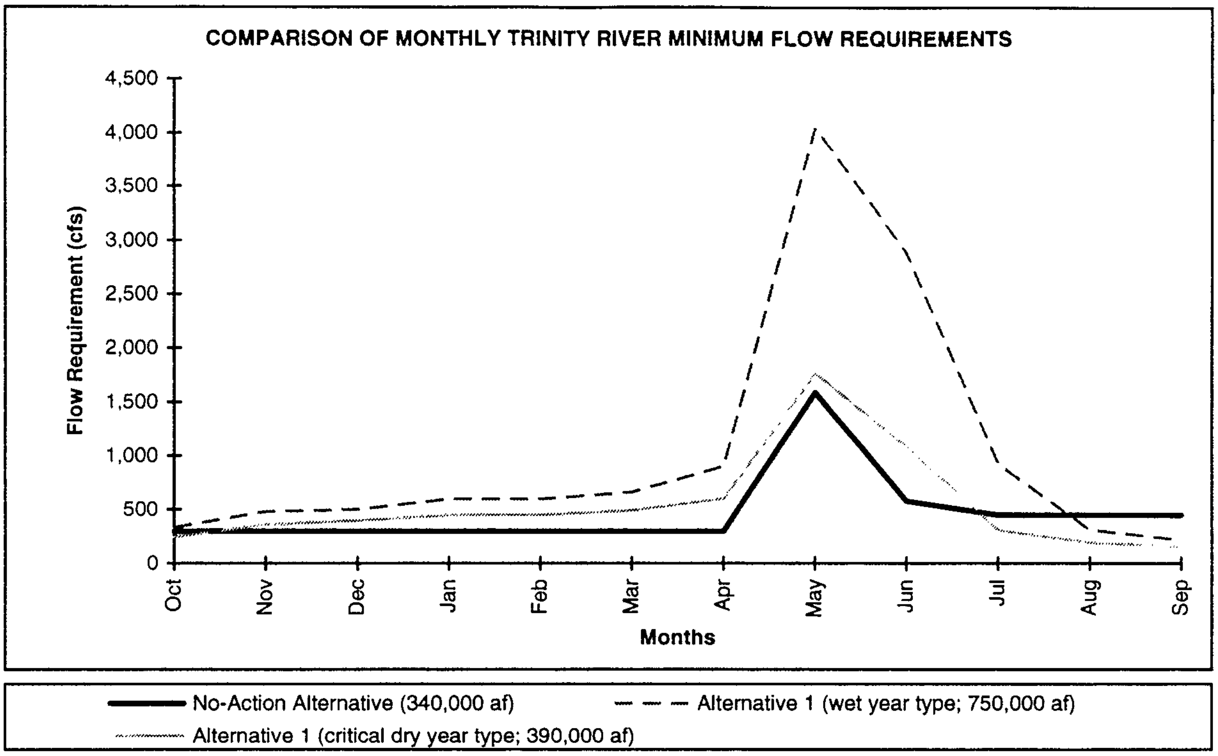
Trinity River Instream Fishery Flow Release Pattern

Alternative 1 assumes implementation of the restoration program. A revised preliminary Trinity River instream fishery flow pattern was developed by the Service for use in the Draft PEIS alternatives. The annual instream fishery flow releases range from 390,000 acre-feet per year in critical dry years to 750,000 acre-feet per year in wet years. The water year type index for these flow requirements is based on the annual inflow to Clair Engle Lake.

In the No-Action Alternative simulation, the Trinity River minimum instream flow volume is 340,000 acre-feet per year in all year types. The preliminary Alternative 1 instream fishery flow release pattern increases the annual release volume by 50,000 acre-feet per year in dry years and by 410,000 acre-feet per year in wet years. A monthly comparison of the No-Action Alternative and the Alternative 1 flow requirements for wet and critically dry year types is presented in Figure III-1.

TABLE III-1
ALTERNATIVE 1 FIRM LEVEL 2 REFUGE WATER SUPPLIES

Refuge	Firm Level 2 Water Supplies (1,000 acre-feet)			Notes
	At Boundary	Conveyance Loss	To Be Diverted	
SACRAMENTO VALLEY REFUGES				
Sacramento NWR	46.4	15.5	61.9	Source: CVP. Conveyance loss on CVP water is 25 percent.
Delvan NWR	20.9	7.0	27.9	Source: CVP. Conveyance loss on CVP water is 25 percent.
Colusa NWR	25.0	8.3	33.3	Source: CVP. Conveyance loss on CVP water is 25 percent.
Sutter NWR	23.5	2.6	26.1	Source: CVP provides Level 2 through exchanges. Conveyance loss on CVP water is 10 percent.
Grey Lodge NWR	35.4	5.2	40.6	Source: Briggs-West Gridley Irrigation District provides Level 1. CVP through exchanges provides remaining Level 2. Conveyance loss on CVP water is 17 percent.
TOTAL FOR SACRAMENTO VALLEY REFUGES	**151.2**	**38.6**	**189.8**	
San Luis NWR	19.0	6.3	25.3	Source: CVP. Conveyance loss on CVP water is 15 percent.
Kesterson NWR	10.0	1.1	11.1	Source: CVP. Conveyance loss on 6,500 acre-feet of CVP water is 15 percent. No loss for 3,500 acre-feet due to delivery through Volta Wasteway.
Volta WMA	13.0	0.0	13.0	Source: CVP. No loss due to delivery through Volta Wasteway.
Los Banos WMA	16.6	2.8	19.4	Source: CVP. Conveyance loss on 10,500 acre-feet of CVP water is 21 percent. No loss for 6,200 acre-feet.
San Joaquin Basin Action Lands				
Freitas	5.3	1.8	7.1	Source: CVP. Conveyance loss on CVP water is 25 percent.
West Gallo	10.8	3.6	14.4	Source: CVP. Conveyance loss on CVP water is 25 percent.
Salt Slough	6.7	1.2	7.9	Source: CVP. Level 2 amount at boundary based on 67 percent of Level 4 amounts at boundary. Conveyance loss on CVP water is 15 percent.
China Island	7.0	1.2	8.2	Source: CVP. Level 2 amount at boundary based on 67 percent of Level 4 amounts at boundary. Conveyance loss on CVP water is 15 percent.
Grasslands Resource Conservation District	125.0	22.1	147.1	Source: CVP. Conveyance loss on CVP water is 15 percent.
Mendota WMA	27.6	0.0	27.6	Source: CVP contract. No losses due to delivery at Mendota Pool.
Merced NWR	15.0	5.0	20.0	Source: Merced Irrigation District in accordance with a FERC agreement. Conveyance loss on water is 25 percent.
East Gallo	8.9	2.9	11.8	Source: Merced River users. Conveyance loss on water is 25 percent.
Kern NWR	9.9	1.5	11.4	Source: CVP. Conveyance loss on CVP water is 13 percent.
Pixley NWR	1.3	0.0	1.3	Source: Well.
TOTAL FOR SAN JOAQUIN VALLEY REFUGES	**276.1**	**49.5**	**325.6**	
TOTAL FOR ALL REFUGES	**427.3**	**88.1**	**515.4**	



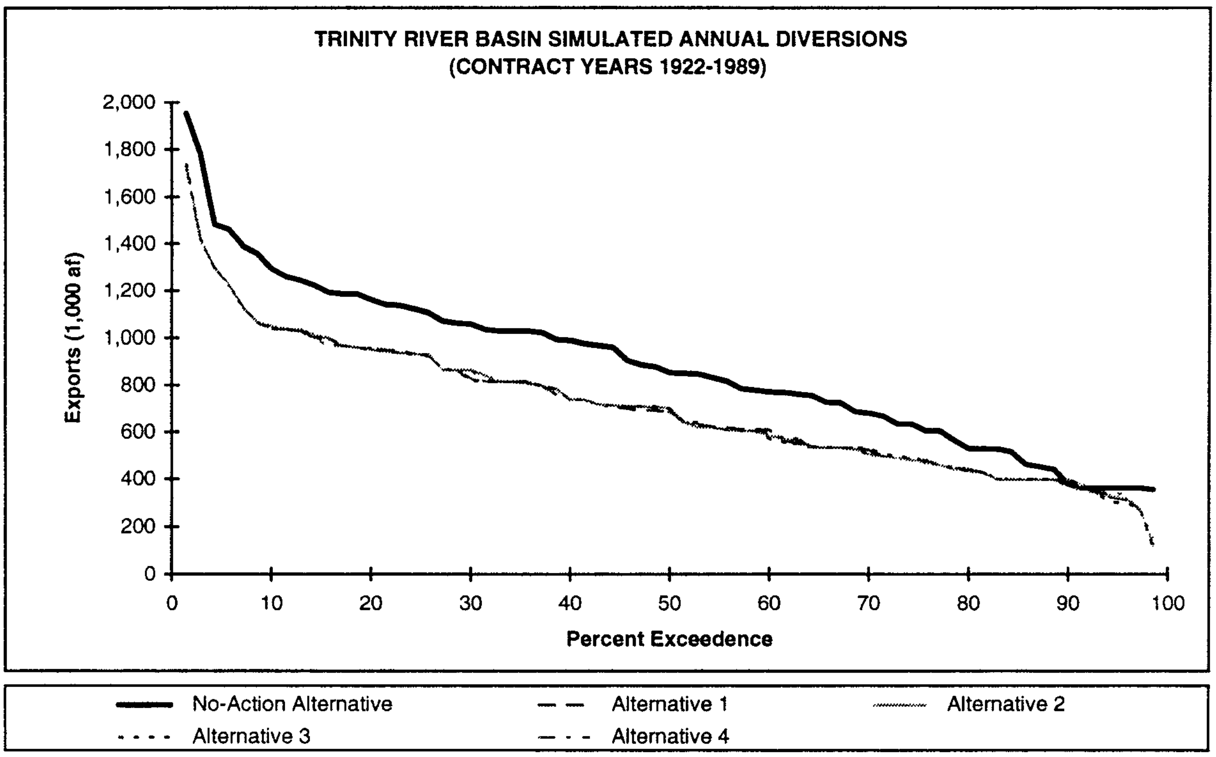


FIGURE III-1
TRINITY RIVER MINIMUM FLOW REQUIREMENTS AND SIMULATED ANNUAL EXPORTS

ALTERNATIVE 1 IMPACTS ON CVP OPERATIONS AND DELIVERIES

This section describes potential changes to the operation of CVP facilities, river flow regimes, and CVP water deliveries that would result from implementation of the CVPIA actions included in Alternative 1. All of the Draft PEIS computer model simulations and analyses were conducted at a programmatic level and are valid on a comparative basis only. A summary comparison of deliveries to CVP contractors in the Alternative 1 simulation, as compared to the No-Action Alternative simulation, is provided in Table III-2. A discussion of the impacts to SWP operations and SWP deliveries south of the Delta is provided in the next section.

TABLE III-2
COMPARISON OF CVP DELIVERIES IN THE ALTERNATIVE 1 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet)		Average Annual Change in CVP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 1	
1922 - 1990	Simulation Period	5,770	5,300	-470
1928 - 1934	Dry Period	4,560	4,050	-510
1967 - 1971	Wet Period	6,310	6,020	-290

Notes:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.

CVP Operations

Trinity River Division. The major change specific to Trinity River Division operations in Alternative 1 is the incorporation of the instream fishery flow release pattern developed by the Service for the Draft PEIS. In Alternative 1, annual instream fishery flow releases range from 390,000 acre-feet per year in critical dry years to 750,000 acre-feet per year in wet years. Average flows down the Trinity River in Alternative 1 increase by about 190,000 acre-feet per year as compared to the No-Action Alternative. A comparison of the frequency distributions of simulated Clair Engle Lake end-of-water year storage for Alternative 1 and the No-Action Alternative is shown in Figure III-2. The increase in Trinity River flow releases in Alternative 1 reduces Clair Engle Lake average end-of-water year storage by about 200,000 acre-feet per year as compared to the No-Action Alternative. CVP Trinity River diversions to Whiskeytown Lake would be reduced by about 180,000 acre-feet per year on an average annual basis to attempt to balance the net demands on Clair Engle Lake. Frequency distributions of the simulated annual diversions from the Trinity River Basin in the No-Action Alternative and Alternative 1 are presented in Figure III-1. The overall reduction in Clair Engle Lake storage results from the increase in fishery flow releases in wetter years, and the low refill potential of the lake.

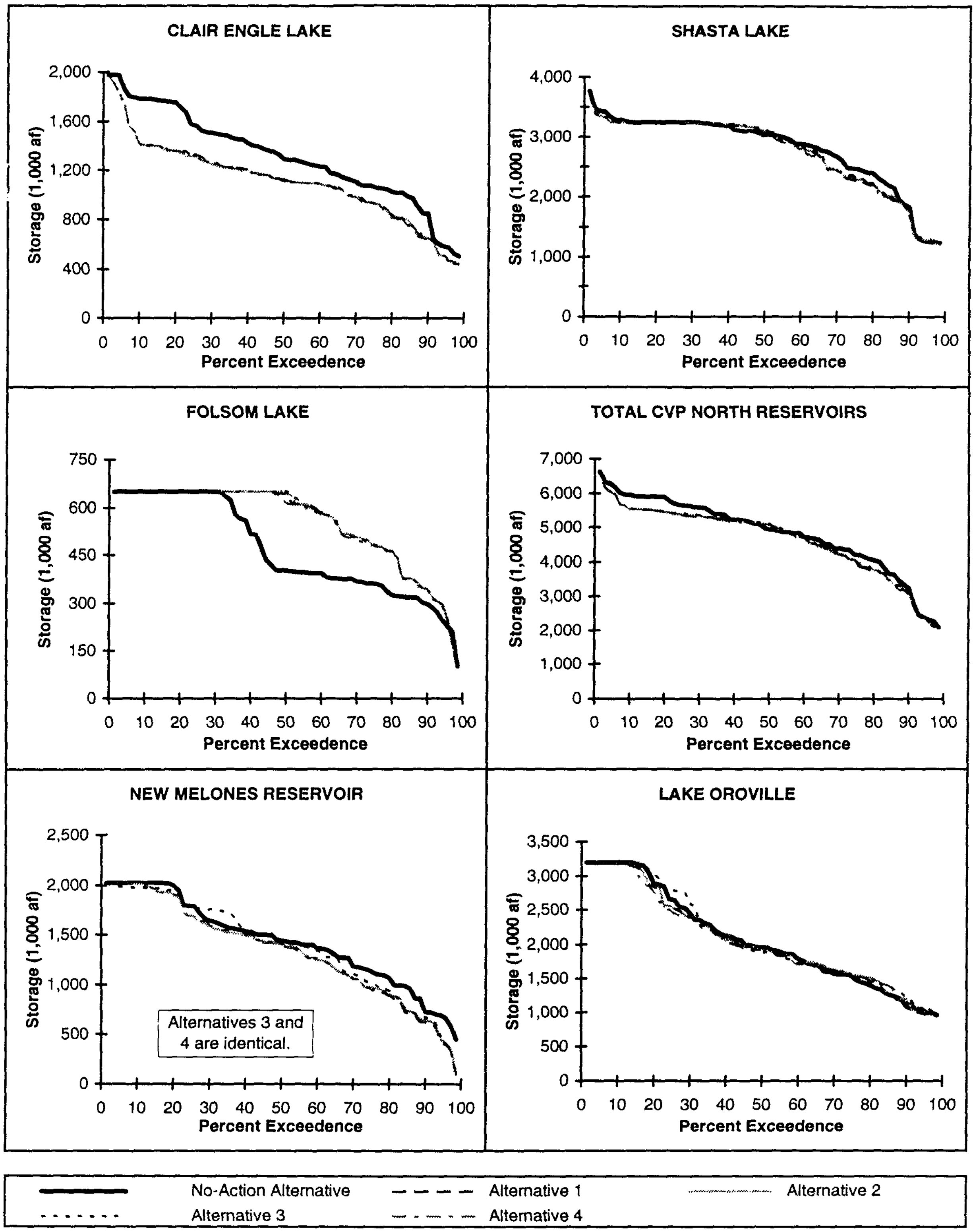


FIGURE III-2

SIMULATED FREQUENCY OF END-OF-WATER YEAR STORAGE 1922-1990

Alternative 1 includes use of (b)(2) water on Clear Creek to attempt to meet target flows. These target flows are achieved in all but critically dry years, when natural inflows to Whiskeytown Lake and diversions from the Trinity River Basin are not sufficient to maintain both the target flows and minimum storage levels in Clair Engle and Whiskeytown lakes. Figure III-3 shows the increase in simulated average monthly Clear Creek flows in Alternative 1 as compared to the No-Action Alternative. The average monthly flows are compared for the 69-year simulation period, as well as for critical dry and wet periods to show the range of Clear Creek flow variation. Figure III-4 shows the increase in simulated monthly Clear Creek flows for the critical dry period 1929 through 1934 and the wet period 1967 through 1971. The increase in flow would result in generally lower water temperatures as compared to the No-Action Alternative.

Shasta and Sacramento River Divisions. The Alternative 1 operations of the Shasta and Sacramento River divisions are affected by the multiple changes to CVP operations associated with (b)(2) Water Management, the delivery of firm Level 2 refuge supplies, and the increase in Trinity River instream fishery flow releases. The increase in Trinity River flow releases decreases the average annual diversions from the Trinity River Basin by about 180,000 acre-feet per year. This reduction of inflow to the Sacramento River requires increased releases from Shasta Lake during spring and summer months for Winter-Run Biological Opinion temperature requirements, downstream water rights, minimum navigational flow requirements, water service contractors, and Delta water quality requirements. During fall and winter months, Shasta releases must be increased to meet (b)(2) target flow and to supply water for export to San Luis Reservoir. The resulting decrease in Shasta Lake end-of-water year storage is shown in the comparison of frequency distributions for Alternative 1 and the No-Action Alternative in Figure III-2. The average annual reduction in Shasta Lake end-of-water year storage is about 60,000 acre-feet per year or 2 percent.

The reduced diversions from the Trinity River Basin under Alternative 1 require increased releases from Shasta Lake to meet the target flows and reduce the operational flexibility to meet winter-run temperature control requirements. This occurs because, although there are no target flows from May 1 through September 30, Shasta Lake releases are still required during this period to maintain water temperatures in the Sacramento River for winter-run chinook salmon. To the extent possible, releases from Shasta Dam during spring and summer months are shifted to the fall and winter months to meet target flows while maintaining summer water temperature levels. The October-through-April Keswick target flows are based on October 1 storage in Shasta Lake and are therefore achieved in all months. A comparison of flows in the Sacramento River below Keswick Dam, Figure III-5, shows that summer flows in Alternative 1 are lower than flows in the No-Action Alternative, and that fall and winter flows are generally similar. Simulated monthly flows in the Sacramento River below Keswick Dam for the dry period 1929 through 1934 and the wet period 1967 through 1971 are shown in Figure III-6. The October-through-April Keswick target flows are based on October 1 storage in Shasta Lake and are therefore achieved in 100 percent of the months.

The flexibility to meet winter run temperature control requirements in Alternative 1 is limited by the reduction in diversions from the Trinity River Basin. Reclamation's PROSIM and temperature models were run iteratively in an attempt to determine spring and summer Shasta

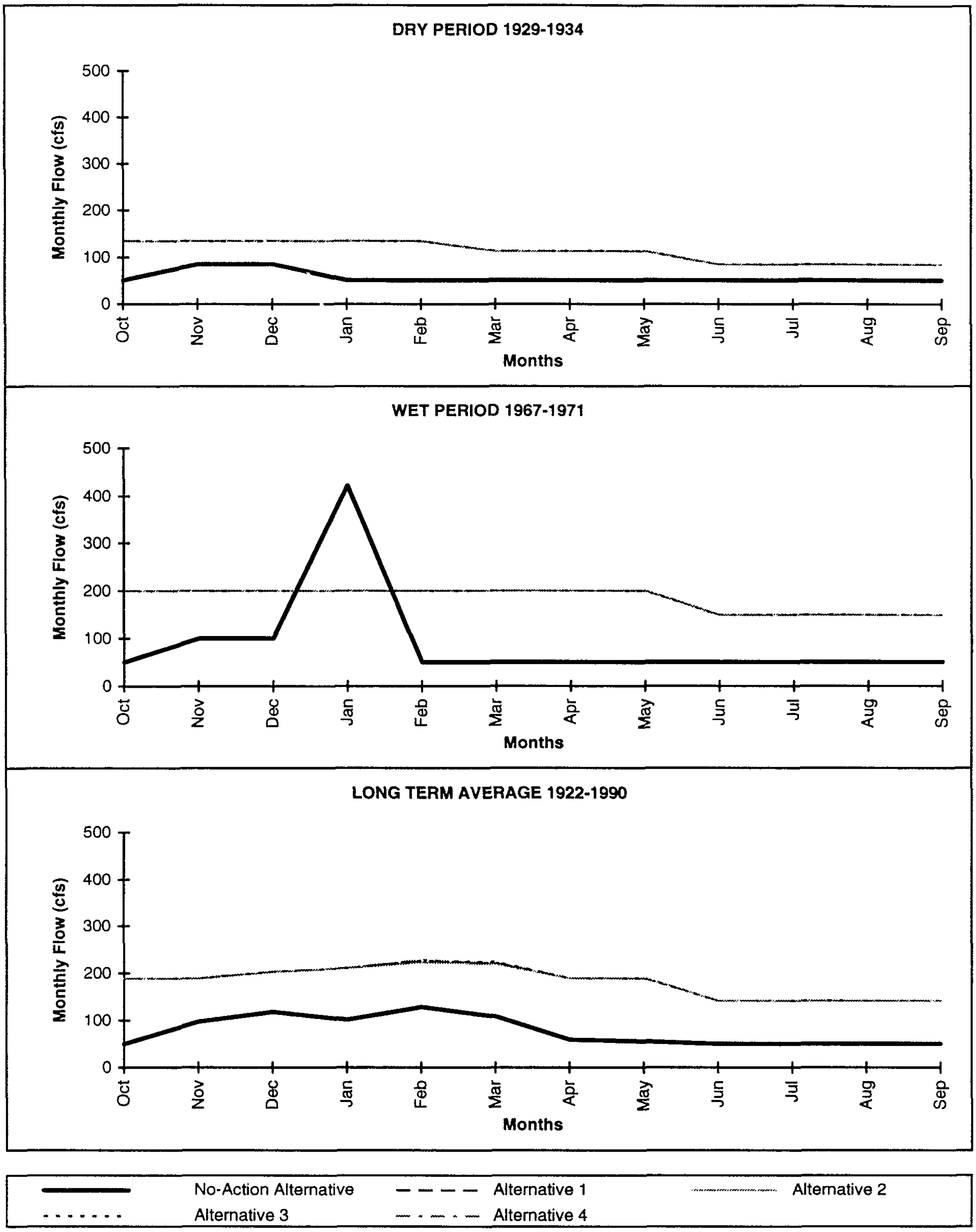


FIGURE III-3
CLEAR CREEK BELOW WHISKEYTOWN
SIMULATED AVERAGE MONTHLY FLOWS

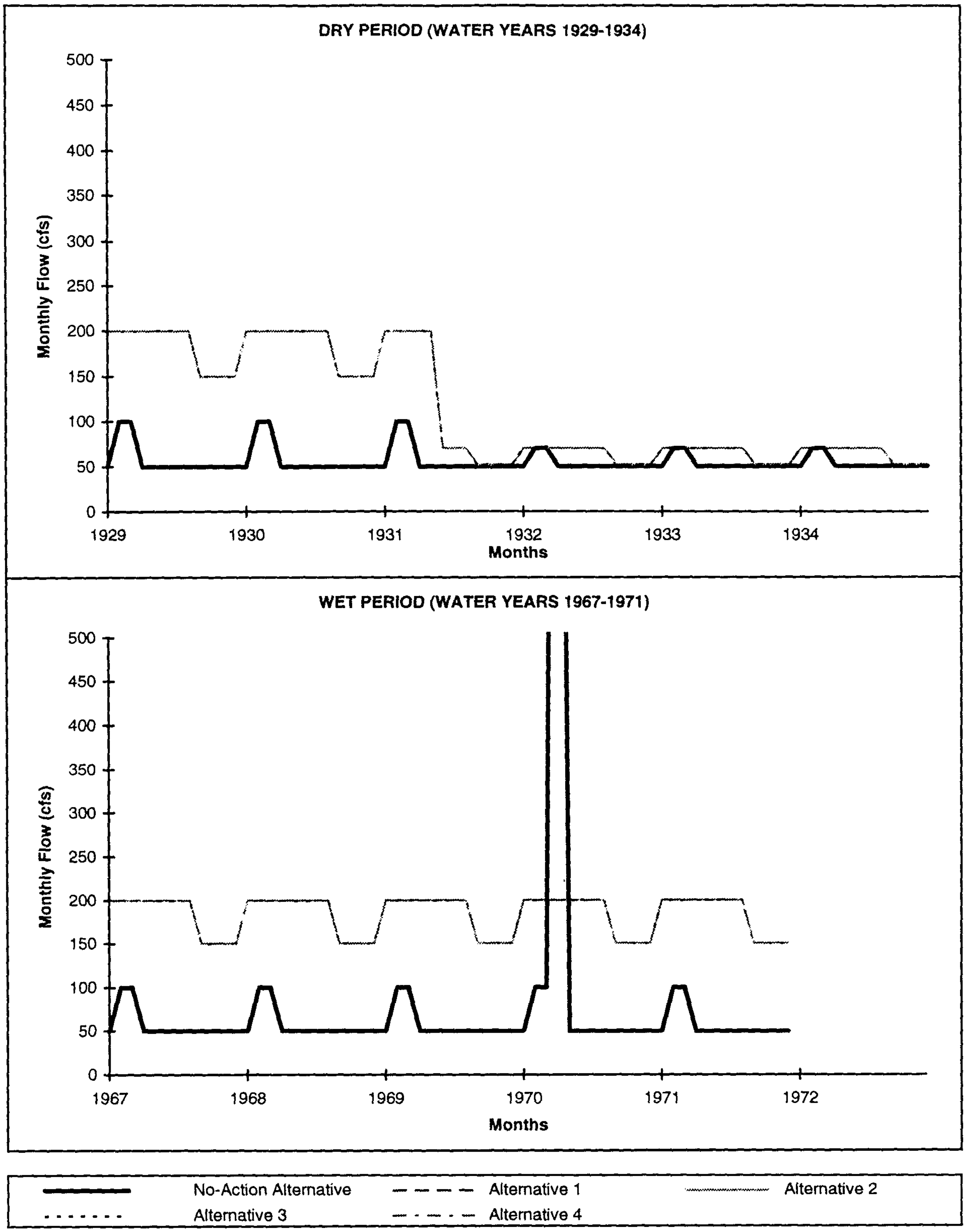


FIGURE III-4

CLEAR CREEK BELOW WHISKEYTOWN SIMULATED MONTHLY FLOWS

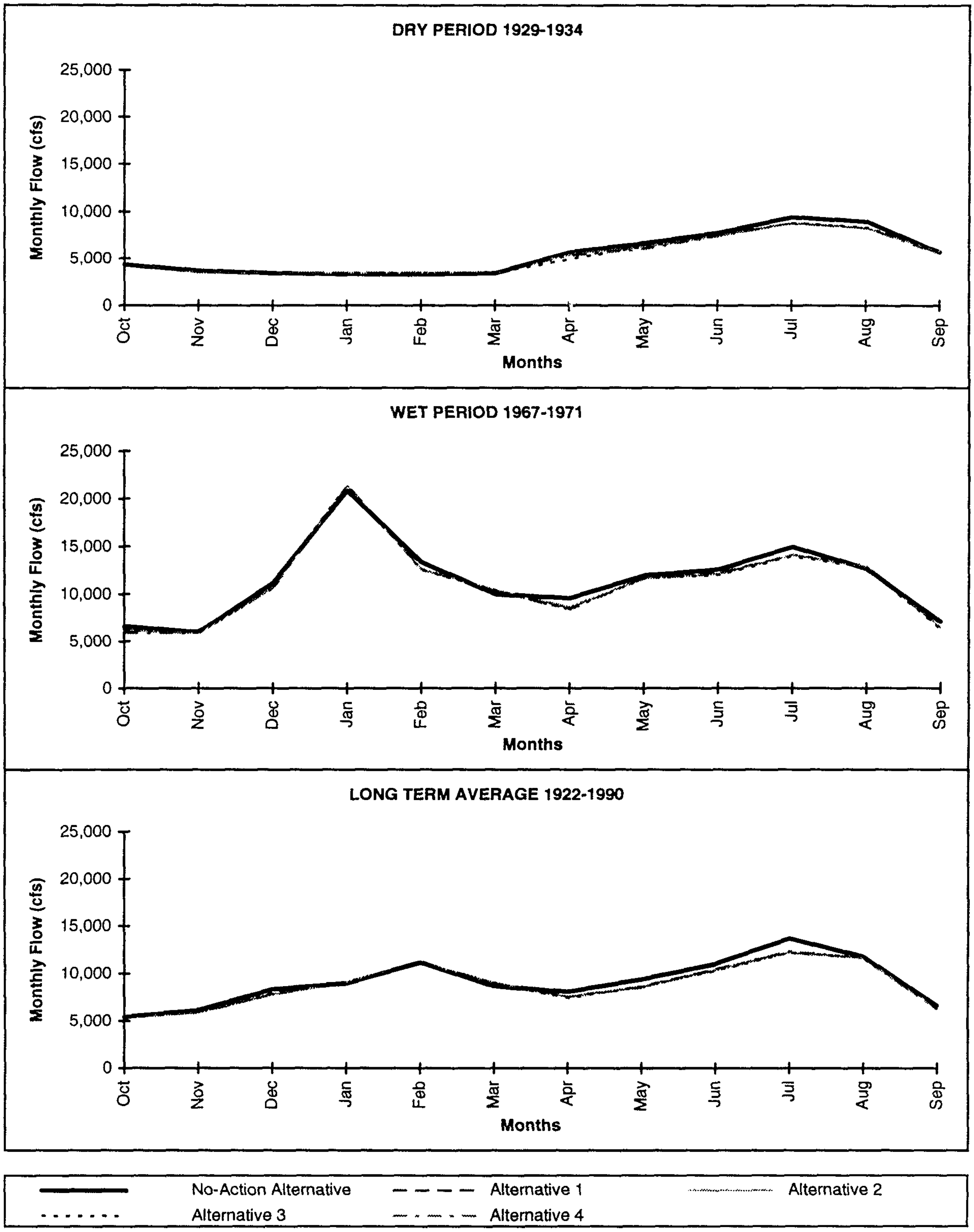


FIGURE III-5
SACRAMENTO RIVER BELOW KESWICK
SIMULATED AVERAGE MONTHLY FLOWS

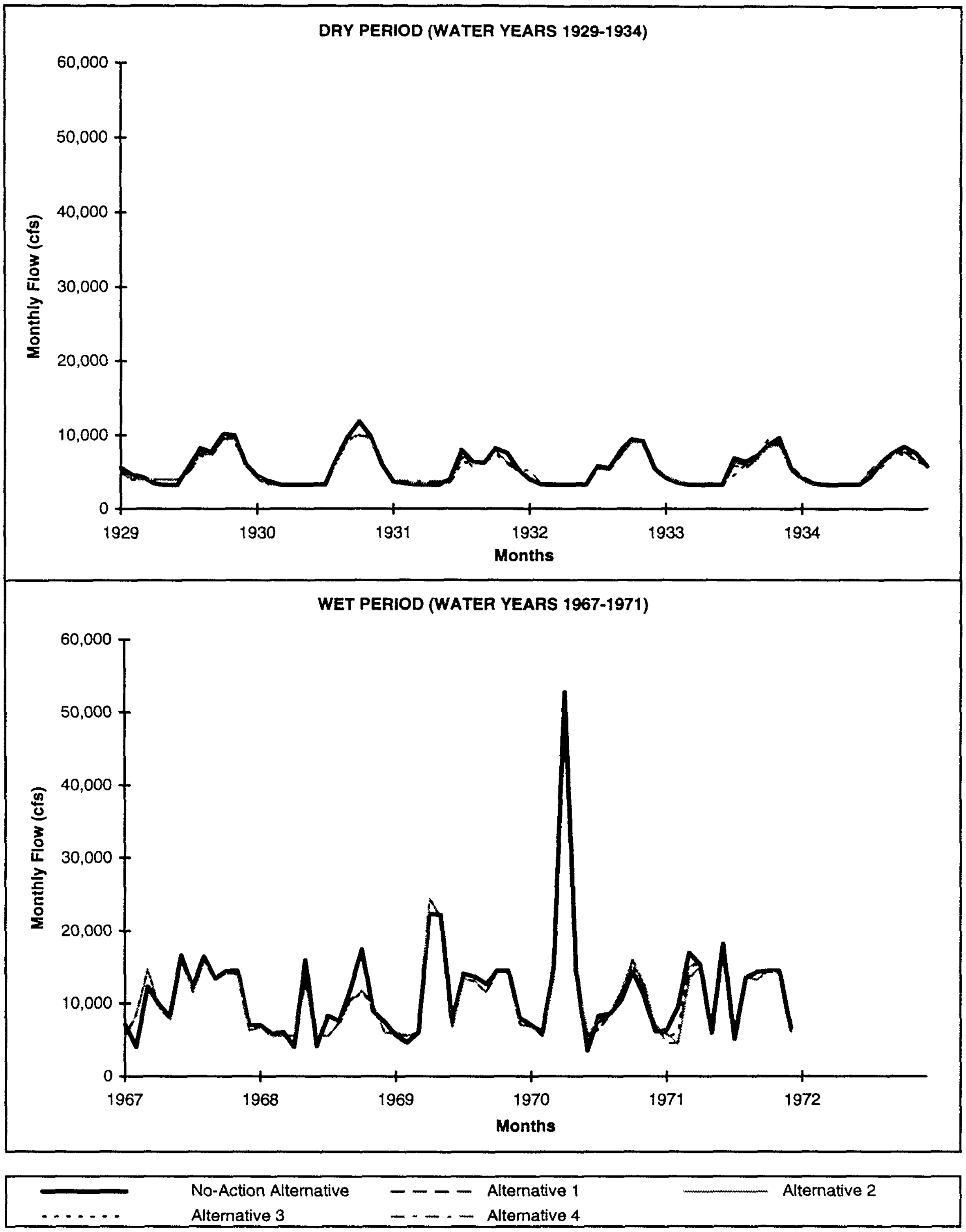


FIGURE III-6

SACRAMENTO RIVER BELOW KESWICK SIMULATED MONTHLY FLOWS

Lake releases that compensate for the reduction in Trinity diversions, while continuing to maintain downstream water temperatures for winter-run salmon at the No-Action level. As shown in Table III-3, average monthly temperature model results for Alternative 1 are generally similar to results for the No-Action Alternative during the critical summer months. Results indicate that temperature would exceed target levels more frequently during spring and fall.

TABLE III-3
RECLAMATION TEMPERATURE MODEL RESULTS FOR SACRAMENTO RIVER BELOW KESWICK DAM, 1922-1990

	Percent of Months with Simulated Average Monthly Temperatures within 0.5 °F of 1993 Winter Run Biological Opinion Target (1)						
Alternative	**April**	**May**	**June**	**July**	**August**	**September**	**October**
No-Action Alternative	100	90	91	94	93	78	96
Alternative 1	99	88	91	93	87	74	94
Alternative 2	99	86	91	94	91	74	94
Alternative 3	97	86	91	93	90	74	96
Alternative 4	99	84	91	94	90	74	94

NOTE:
(1) Temperature Control not in effect January through March and November through December. Target location for Bend Bridge and Jelly's Ferry based on Sacramento River Index.

These differences are attributable to conditions during critical dry years, where re-consultation with NMFS would be necessary under the biological opinion. Table III-4 compares average temperature simulation results in non-critical years.

Changes to Folsom Lake operations for (b)(2) water purposes also affect the need for Shasta Lake releases, and resulting Sacramento River flows below Keswick Dam. In Alternative 1, increased fall and winter Folsom Lake releases, to attempt to meet American River target flows. These increased flows meet a greater portion of the downstream Delta export and water quality requirements, reducing the need for Shasta Lake releases, which may be in excess of the Keswick target flows. Conversely, in some years lower Folsom Lake summer releases may require higher summer Shasta Lake releases for Delta water rights and water quality requirements. The integrated operations of Shasta and Folsom lakes were balanced to try to meet as many of the (b)(2) water objectives as possible, while still fulfilling existing CVP obligations and operational criteria as defined under the No-Action Alternative.

TABLE III-4
RECLAMATION TEMPERATURE MODEL RESULTS FOR SACRAMENTO RIVER BELOW KESWICK DAM FOR NON-CRITICAL YEARS 1922 - 1990

	Percent of Months with Simulated Average Monthly Temperatures within 0.5 °F of 1993 Winter-Run Biological Opinion Target (1)						
Alternative	April	May	June	July	August	September	October
No-Action Alternative	100	91	97	100	99	87	100
Alternative 1	99	90	96	100	96	83	100
Alternative 2	99	87	96	100	100	83	100
Alternative 3	99	87	96	99	99	84	100
Alternative 4	99	87	96	100	99	83	100

NOTES:
(1) Temperature Control not in effect January through March and November through December. Target location for Bend Bridge and Jelly's Ferry based on Sacramento River Index.

Results for the critical years 1924, 1929, 1931, 1932, 1933, 1934, and 1977 are not included. Per the 1993 Winter-Run Biological Opinion, reconsultation would be expected to occur in these years because simulated end-of-water year storage in Shasta Lake is less than 1.9 million acre-feet per year.

As system demands increase and operational criteria become more complex, the ability of the CVP to respond to short-term increases in the need for water is reduced. In most dry and critical dry years, Shasta Lake releases are governed by water rights and fisheries objectives including the target flows, the Winter-Run Biological Opinion, and Delta water quality requirements. CVP Delta exports are generally limited to incidental Delta inflows resulting from upstream releases for fisheries purposes and return flows from water rights diversions.

Simulated average monthly flows in the Sacramento River below Knights Landing for the No-Action Alternative and Alternative 1 simulations are presented in Figure III-7. These flows reflect operational changes upstream of Knights Landing including releases from Shasta and Whiskeytown lakes for target flows and from reductions in diversions from the Trinity River Basin. The average monthly flows decrease slightly in June through August; however, the flow changes are small in proportion to total flows at Knights Landing. Simulated monthly flows in the Sacramento River below Knights Landing for the dry period 1929 through 1934 and the wet period 1967 through 1971 are shown in Figure III-8.

American River Division. Alternative 1 Folsom Lake and American River operations are directly affected by attempts to meet flow targets on the American River, as well as the changes to Trinity, Shasta, and Sacramento River division operations described above. The primary fishery goals on the American River are to increase Folsom Lake September end-of-water year storage and to provide higher, more stable fall and winter river flows. The CVP's operational ability to meet the flow targets is limited by the highly variable American river flows, relatively small Folsom Lake storage capacity, and the high M&I and water rights demands.

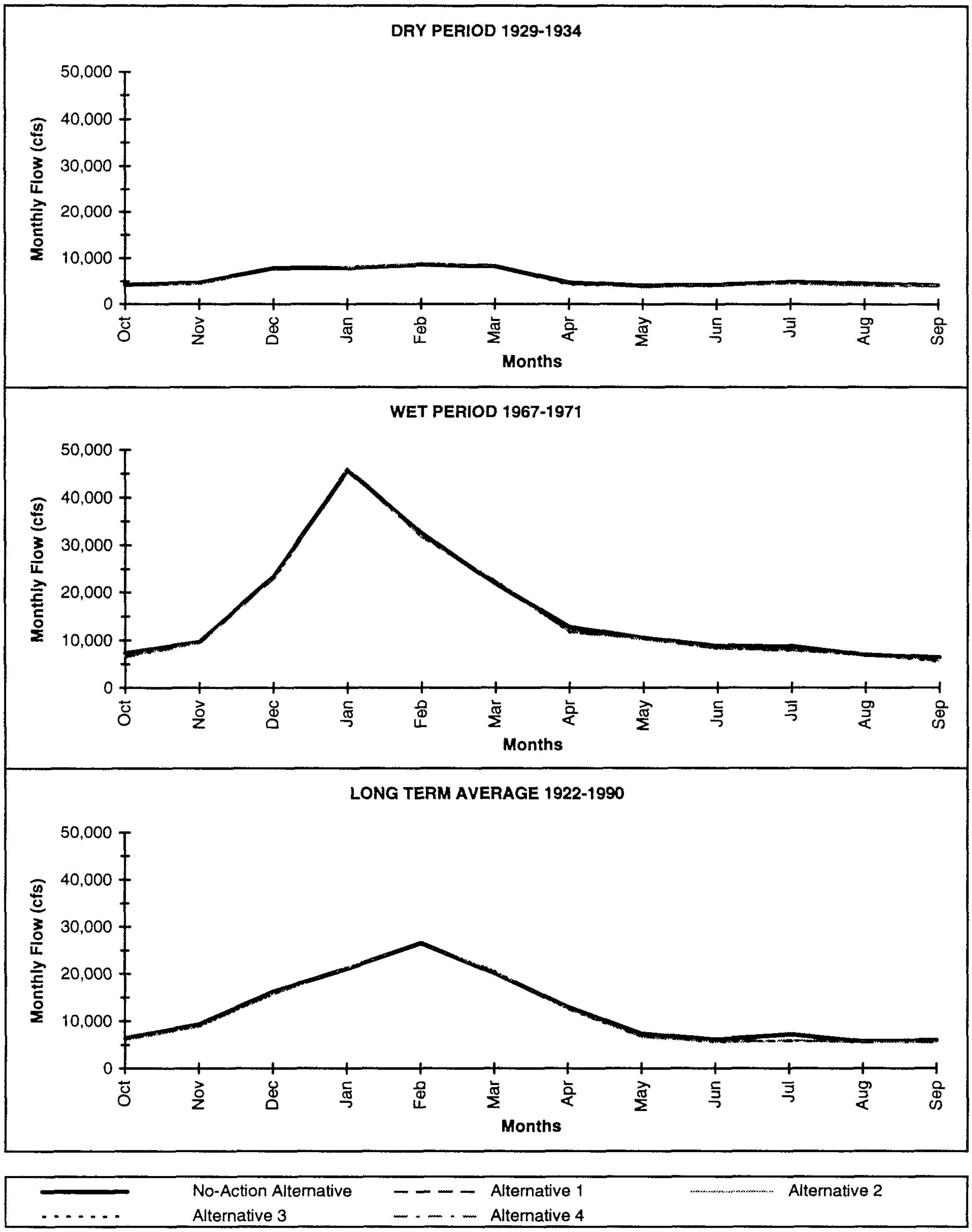


FIGURE III-7
SACRAMENTO RIVER AT KNIGHTS LANDING
SIMULATED AVERAGE MONTHLY FLOWS

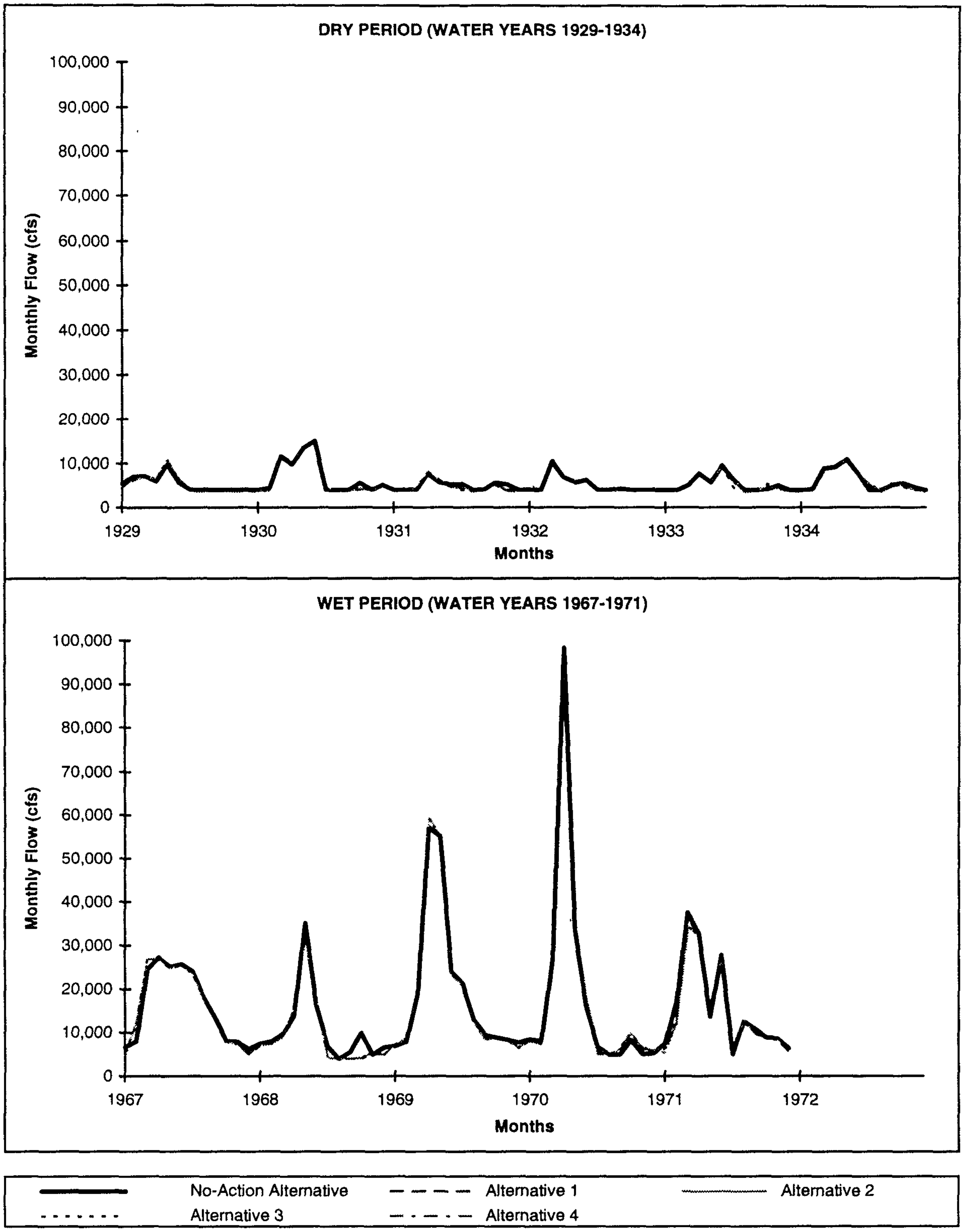


FIGURE III-8

SACRAMENTO RIVER AT KNIGHTS LANDING SIMULATED MONTHLY FLOWS

The frequency distribution in Figure III-2 shows the increase in Alternative 1 Folsom Lake end-of-water-year storage as compared to the No-Action Alternative. Average end-of-water-year lake storage increases by about 80,000 acre-feet per year in comparison to the No-Action Alternative. The AFRP September storage target of 610,000 acre-feet per year is met in about 50 percent of the 69 years in the Draft PEIS simulation period. The re-operation of Folsom Lake average monthly storage in the dry, wet, and 69-year average simulation periods is shown in Figure III-9.

Folsom Lake releases are shifted from the spring and summer months to the fall and winter months in an attempt to meet target flows on the American River below Nimbus Dam. These target flows are based on the storage/inflow relationship developed as part of the PEIS (b)(2) Water Management analysis discussed previously. The target flows in the October-through-February period are achieved in 100 percent of the months in wet, above normal, and below normal water years. For the same period, target flows are met in 80 percent of the dry years and 40 percent of the critical dry years. Simulated average monthly flows in the American River below Nimbus Dam in the No-Action Alternative and Alternative 1 are compared in Figure III-10. The re-operation of Folsom Lake releases is most evident in the comparison of average

monthly flows for the dry period 1929 through 1934. Simulated monthly flows in the American River below Nimbus Dam for the dry period 1929 through 1934 and the wet period 1967 through 1971 are shown in Figure III-11.

The integrated operations of Shasta and Folsom lakes were balanced in an attempt to meet as many of the (b)(2) water objectives as possible, while still fulfilling existing CVP obligations and operational criteria as defined under the No-Action Alternative. This was particularly difficult during summer periods when the objective was to decrease releases on both the Sacramento and American rivers to provide additional September storage to help meet fall and winter flow targets. The ability to decrease summer releases is constrained by CVP obligations to provide water for existing minimum flow requirements, CVP M&I and agricultural contract obligations, water rights holders, and Delta water quality requirements. The reduction in Trinity River Basin diversions to the Sacramento River also impacts the ability to re-operate Folsom Lake releases.

Eastside Division. In Alternative 1, New Melones Reservoir would be operated in an attempt to completely meet target flows in the Stanislaus River in the months of July through March, and partially meet Stanislaus River target flows during April through June in non-critical years. Because of the limited available water supply to the CVP in the Stanislaus River watershed, no change in instream flow objectives is made during critically dry years, as compared to the No-Action Alternative.

The frequency distribution in Figure III-2 shows the end-of-water year storage levels in New Melones Reservoir in the No-Action Alternative and Alternative 1 simulations. In general, reservoir storage levels are lower in Alternative 1 than in the No-Action Alternative because of larger releases from New Melones Reservoir for higher instream flows in non-critical years.

The resulting operation would meet July-through-March target flows in all years, and would meet or partially meet target flows during the April-through-June period in some but not all years.

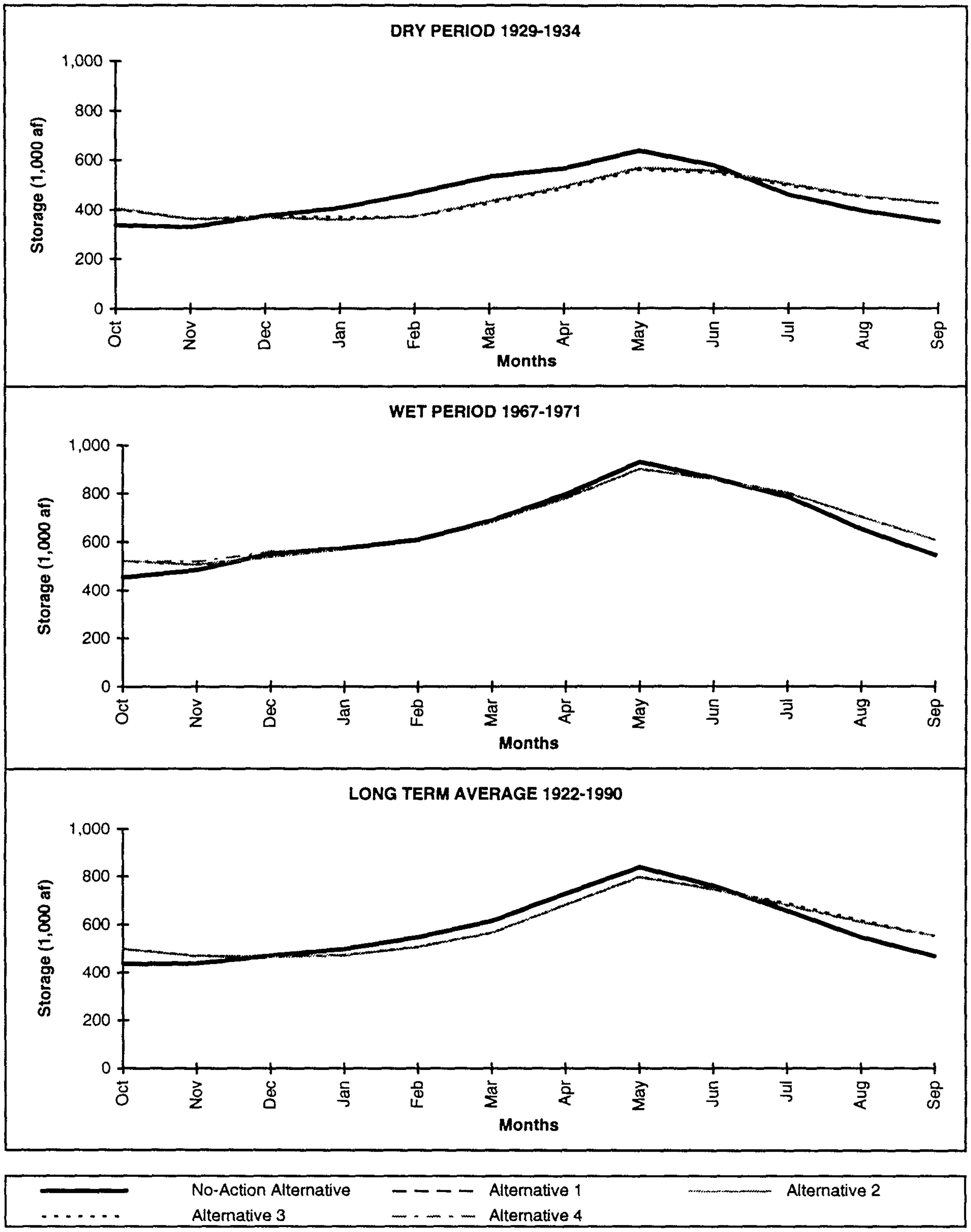


FIGURE III-9

SIMULATED FOLSOM LAKE AVERAGE END-OF-MONTH STORAGE

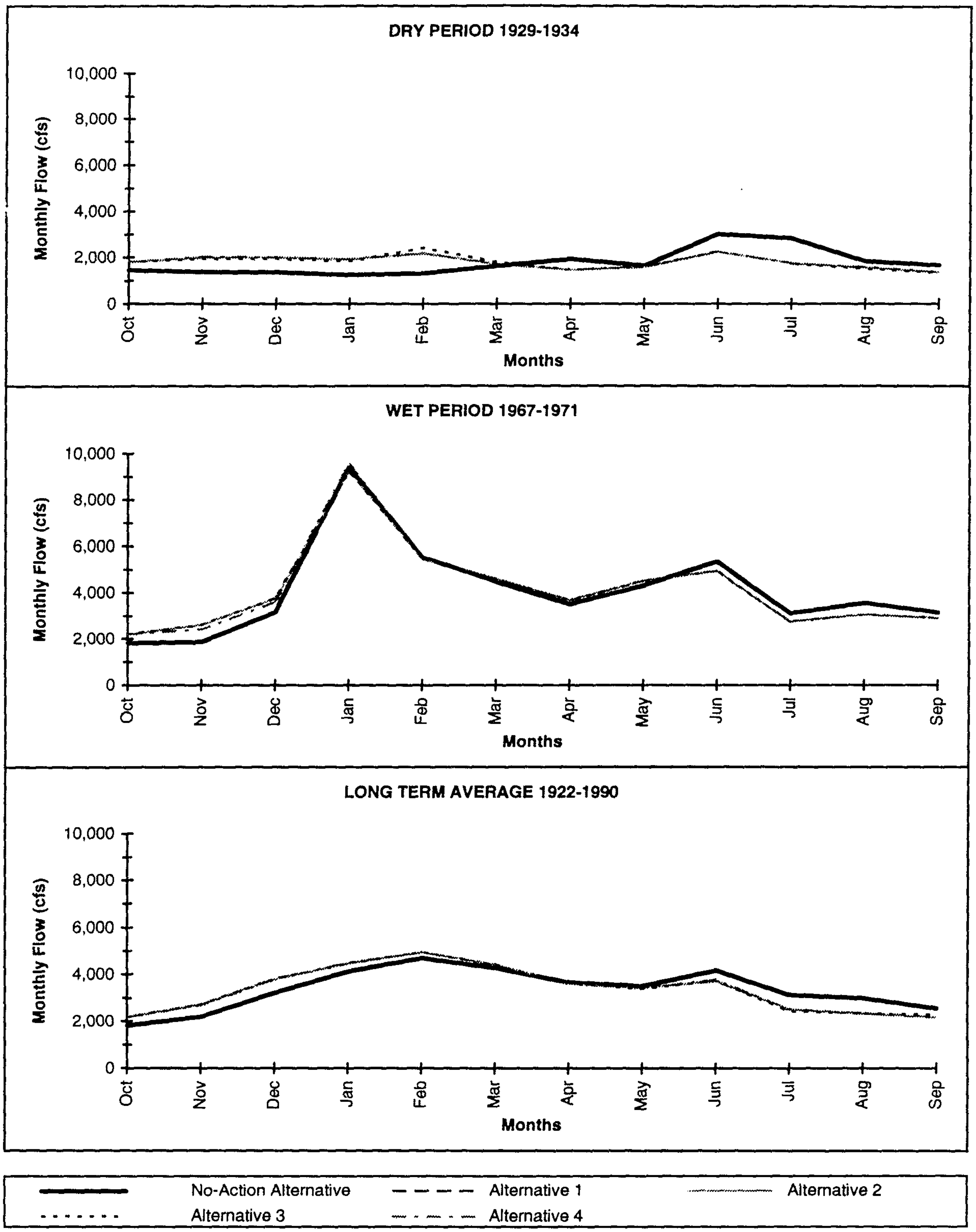


FIGURE III-10

AMERICAN RIVER BELOW NIMBUS SIMULATED AVERAGE MONTHLY FLOWS

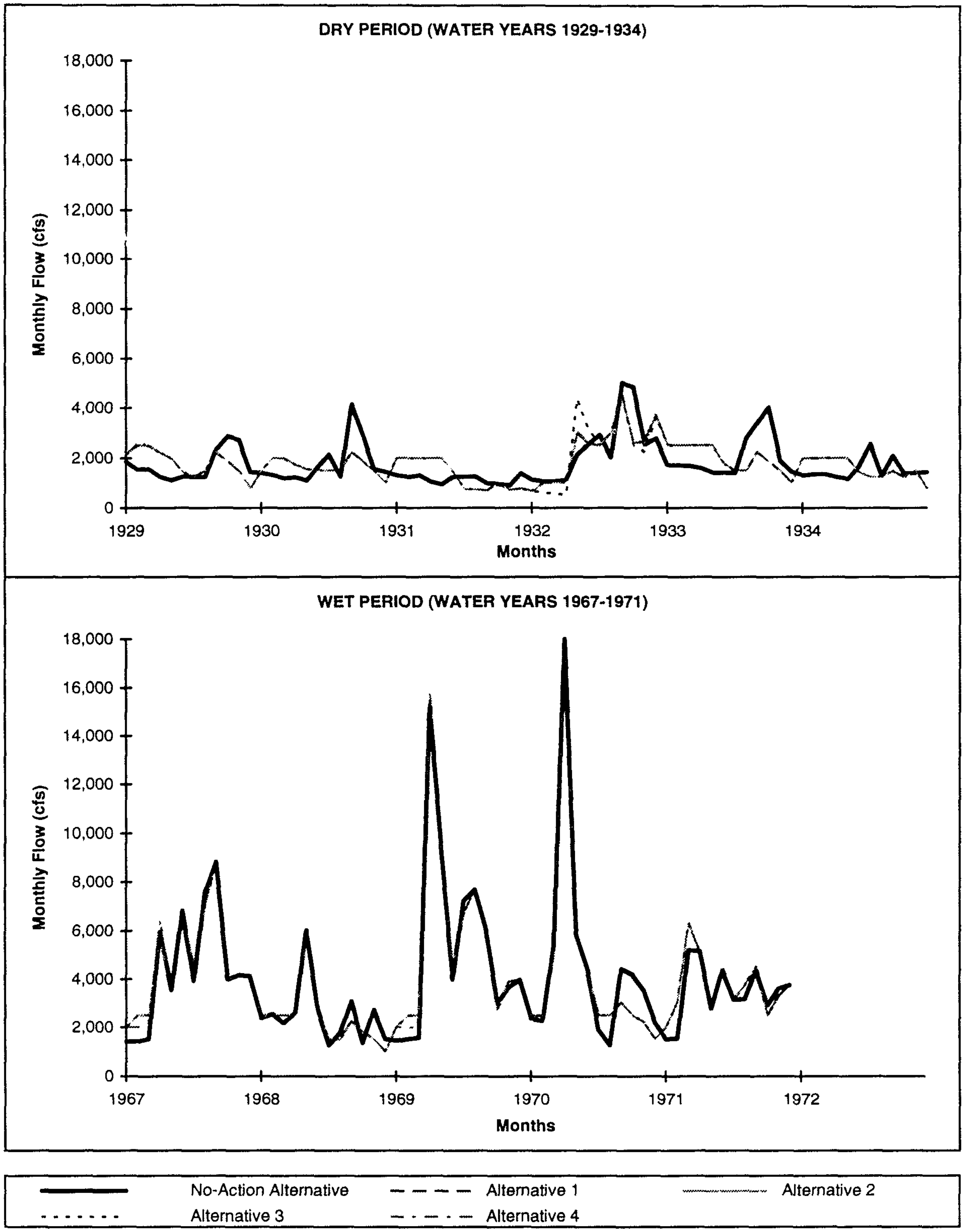


FIGURE III-11

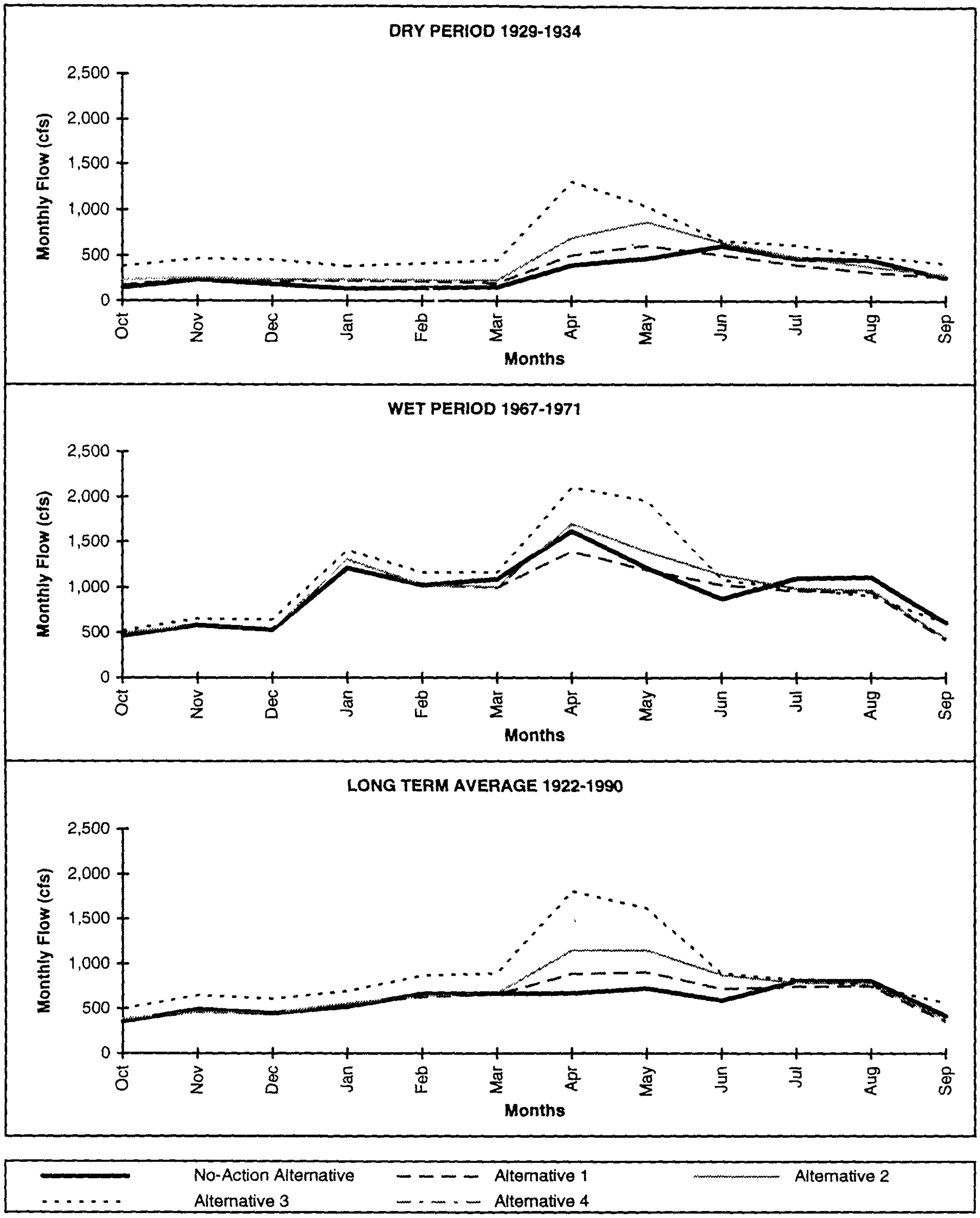
AMERICAN RIVER BELOW NIMBUS SIMULATED MONTHLY FLOWS

Simulated average monthly flows in the Stanislaus River below Goodwin Dam in the No-Action Alternative and Alternative 1 simulations are shown in Figure III-12. As a result of the reduced storage conditions in New Melones Reservoir, the threshold for maximum water quality releases during water deficient years is invoked in one additional year during the dry simulation period of 1929-1934, and results in lower average monthly flows during June, July, and August in that period. Simulated monthly flows in the Stanislaus River below Goodwin Dam for the dry period 1929 through 1934 and the wet period 1967 through 1971 are shown in Figure III-13.

Simulated average monthly flows in the San Joaquin River at Vernalis in the No-Action Alternative and Alternative 1 are shown in Figure III-14. Simulated monthly flows in the dry period 1929 through 1934 and the wet period 1967 through 1971 are shown in Figure III-15. Although the changes in flows resulting from modified Stanislaus River operations affect the flow at Vernalis, the changes are relatively small compared to the total flow at Vernalis. The frequency distribution of simulated monthly water quality on the San Joaquin River at Vernalis during irrigation season (April - August) and non-irrigation season (September - March) for the No-Action Alternative and Alternative 1 is shown in Figures III-16. The figures show that for both the irrigation and non-irrigation seasons, the frequency with which water quality exceeds the standard increases in Alternative 1 over the No-Action Alternative. The increase in the salinity concentration during the irrigation season occurs during the driest 10 percent of the simulated years, and corresponds to periods when releases from New Melones Reservoir for water quality would be limited by available supplies. Salinity concentration increases during the non-irrigation season would primarily result from the increase in deliveries and subsequent return flows from the refuges in the San Joaquin Valley.

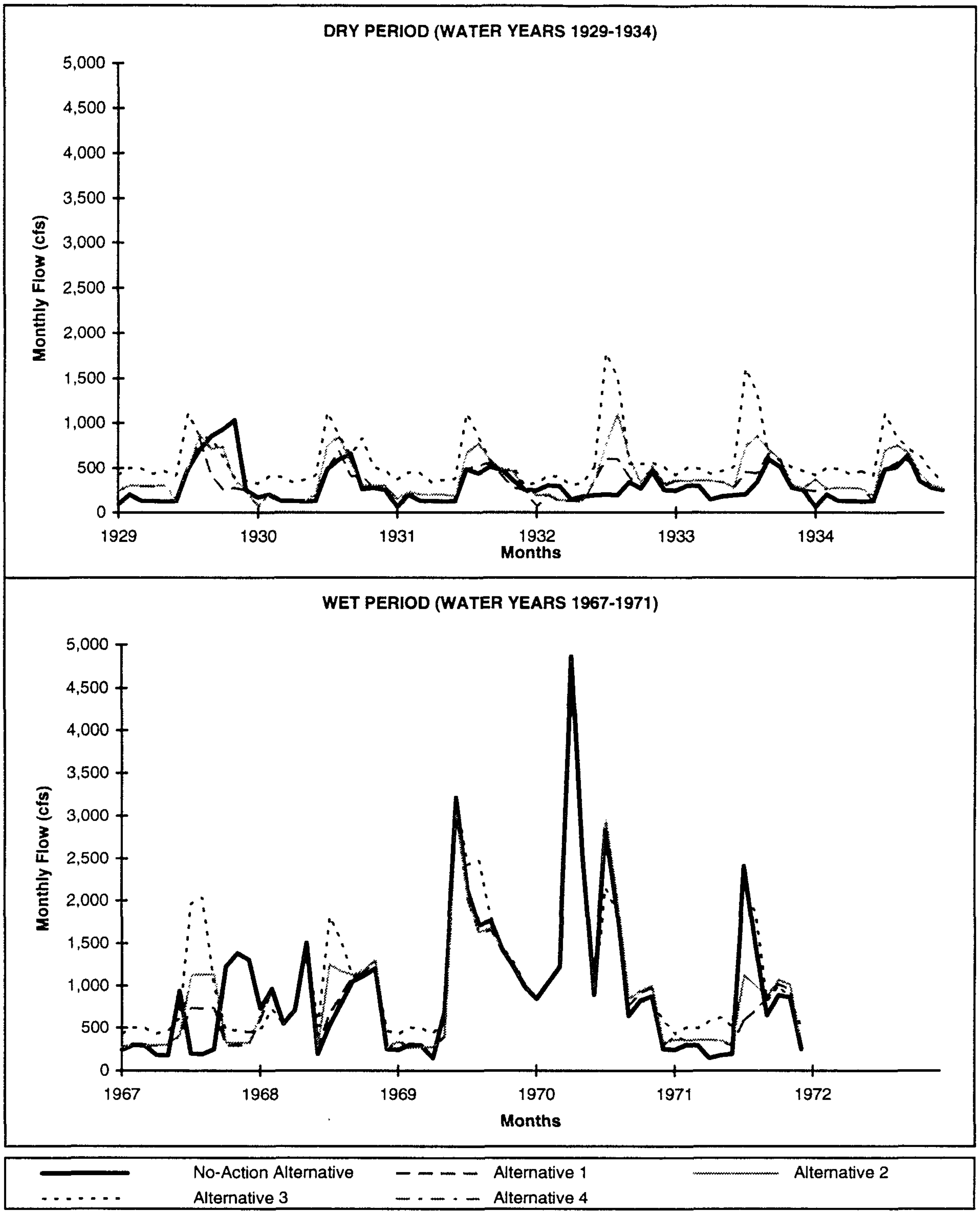
Delta Division. Impacts to operations of the Delta Division in Alternative 1 are a result of reductions in diversions from the Trinity River Basin, and of the combined changes to CVP upstream operations for Whiskeytown, Shasta, Folsom, and New Melones lakes in the attempt to meet target flows. In comparison to the No-Action Alternative simulation, average annual Delta inflows in Alternative 1 are reduced by approximately 240,000 acre-feet per year. Compared to the No-Action Alternative average annual Delta inflow of about 23 million acre-feet per year, this is a reduction of about 1 percent.

Figure III-17 shows the change in simulated average monthly Tracy exports for the dry, wet, and long-term average periods. The figure shows an increase in October-through-January average monthly Tracy exports, for the dry and long-term average conditions, because of the increased upstream CVP releases to meet target flows. In many years, these combined upstream reservoir releases exceed the maximum pumping capacity of Tracy Pumping Plant. In contrast, the Alternative 1 average monthly March-through-September Tracy exports are lower because of decreased spring and summer Trinity River Basin diversions to the Sacramento River, and reduced summer upstream CVP reservoir releases. The net impact is a reduction of about 250,000 acre-feet per year, or 10 percent, in average annual CVP exports through Tracy Pumping Plant. The frequency distribution in Figure III-18 shows the Alternative 1 decrease in annual Tracy Pumping Plant exports as compared to the No-Action Alternative.



NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

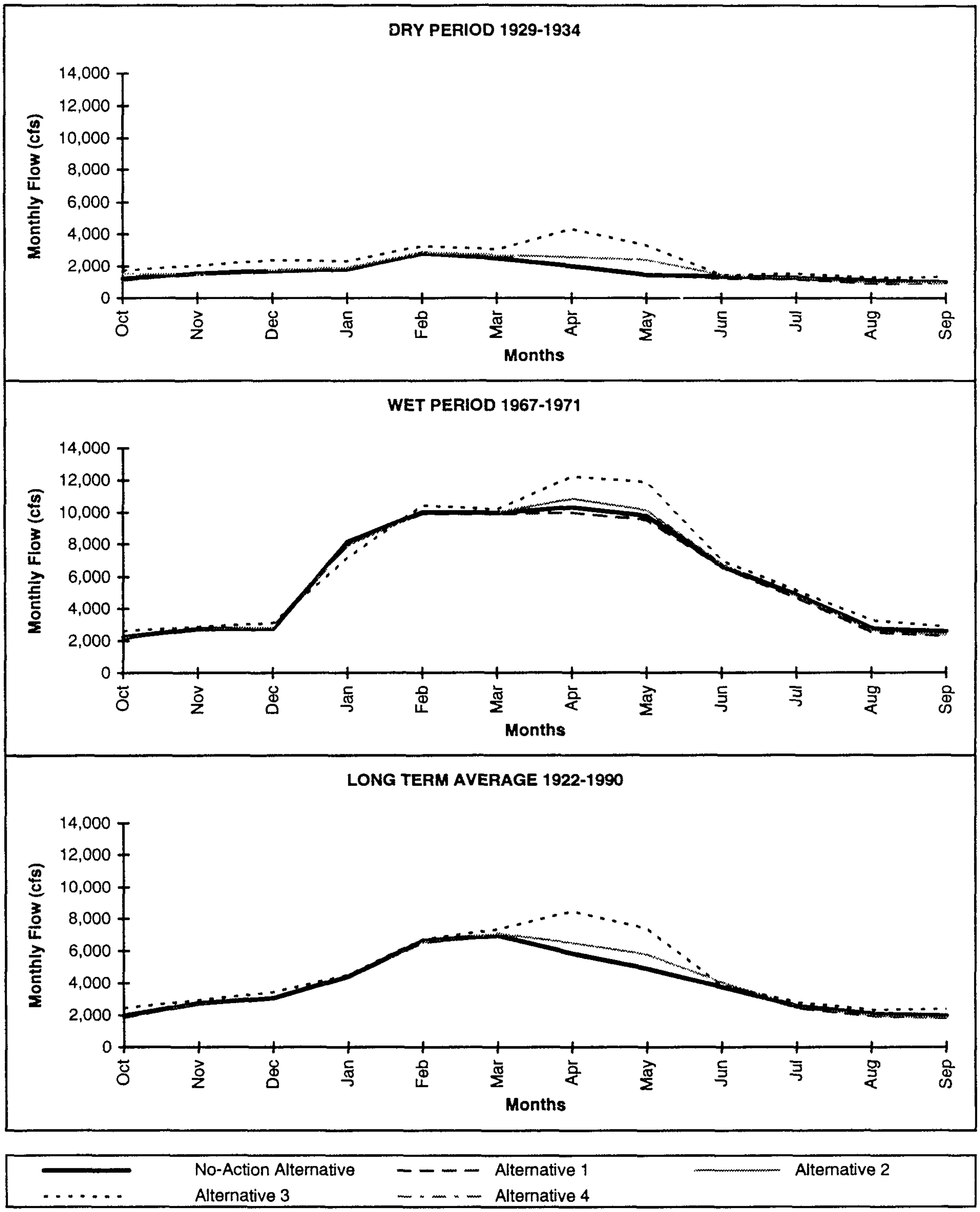
FIGURE III-12
STANISLAUS RIVER BELOW GOODWIN
SIMULATED AVERAGE MONTHLY FLOWS



NOTE: Simulated monthly flows for Alternatives 3 and 4 are identical.

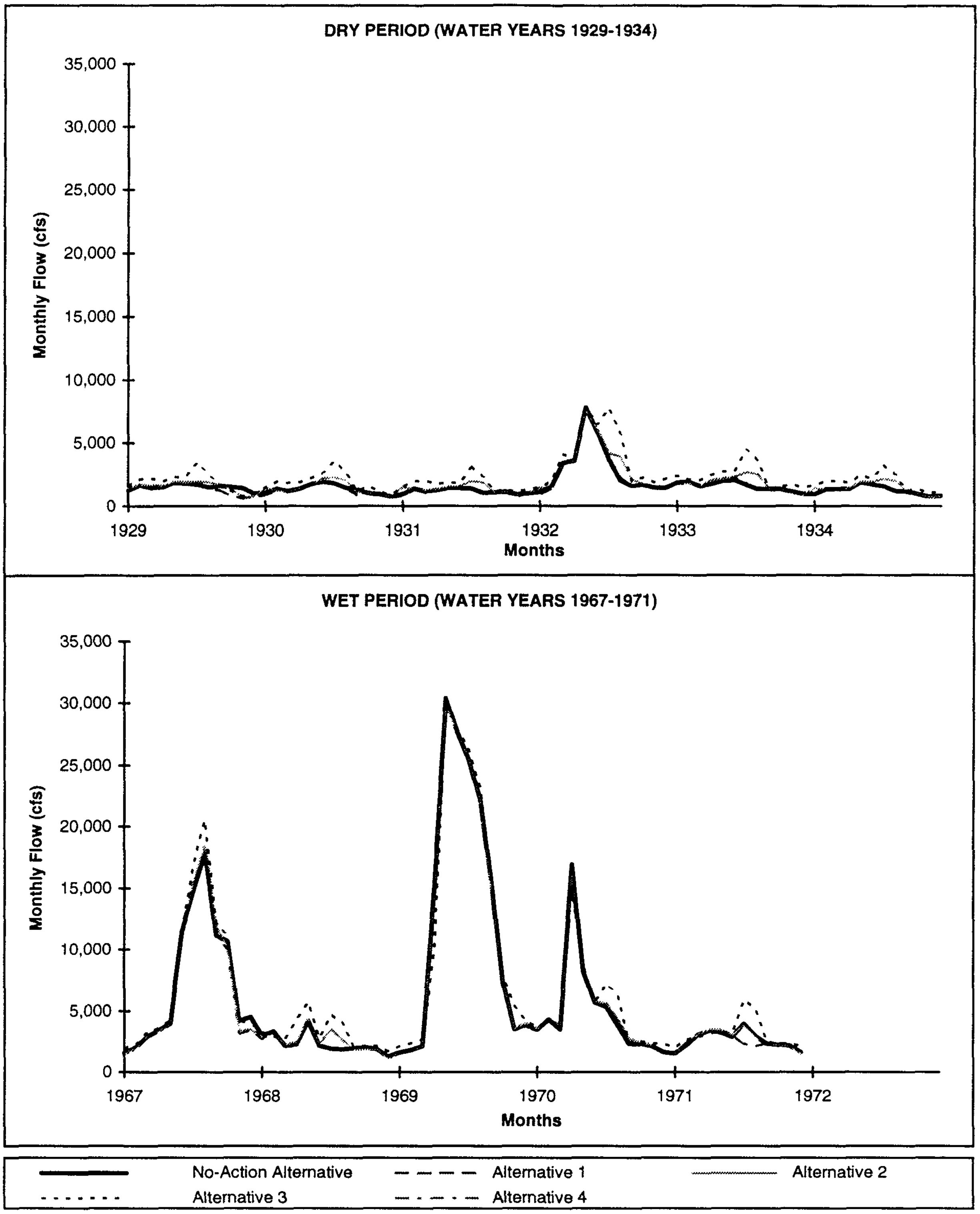
FIGURE III-13

STANISLAUS RIVER BELOW GOODWIN SIMULATED MONTHLY FLOWS



NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

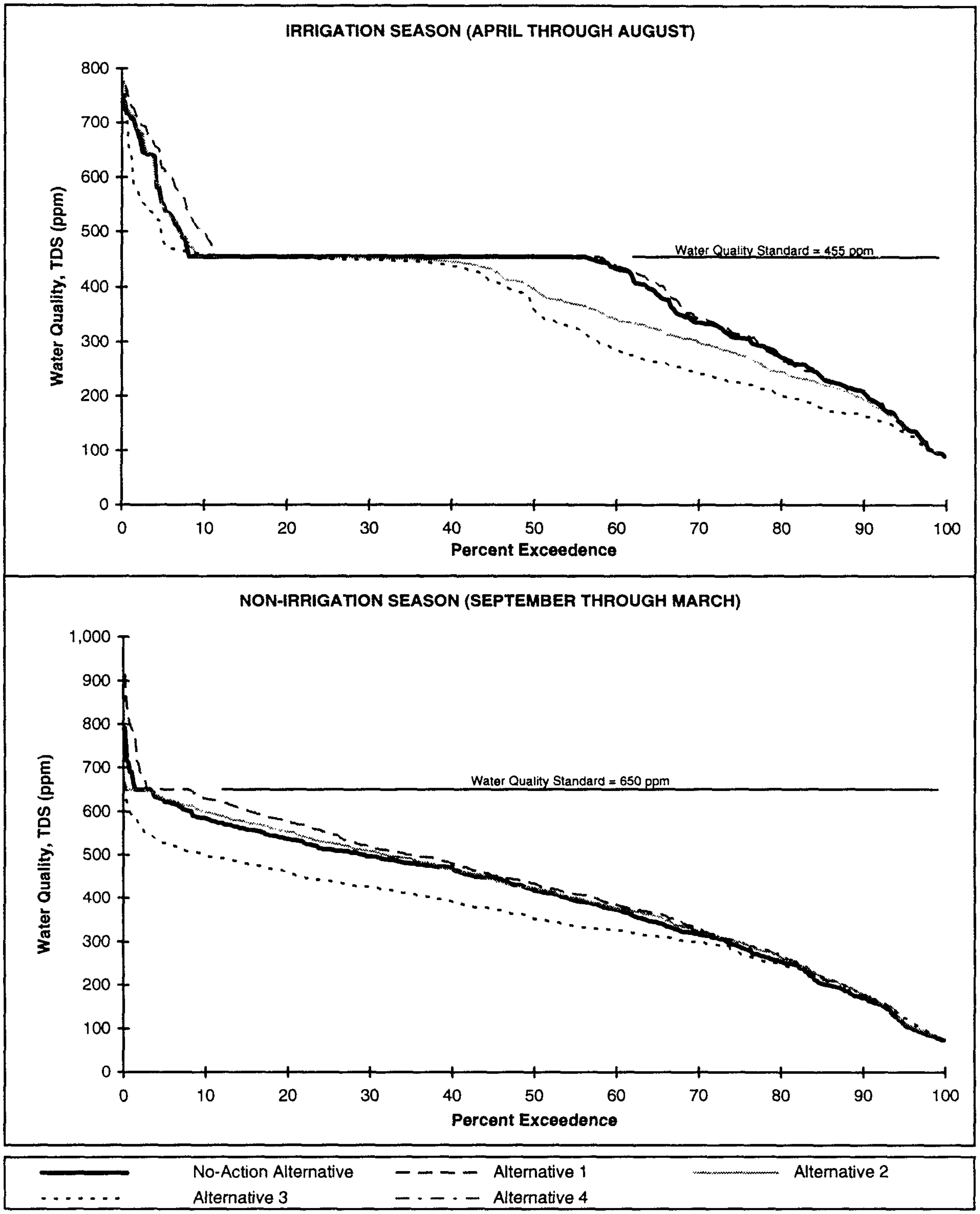
FIGURE III-14
SAN JOAQUIN RIVER AT VERNALIS
SIMULATED AVERAGE MONTHLY FLOWS



NOTE: Simulated monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-15

SAN JOAQUIN RIVER AT VERNALIS SIMULATED MONTHLY FLOWS



NOTE: Water quality conditions under Alternatives 3 and 4 are identical.

FIGURE III-16

SIMULATED MONTHLY WATER QUALITY AT VERNALIS

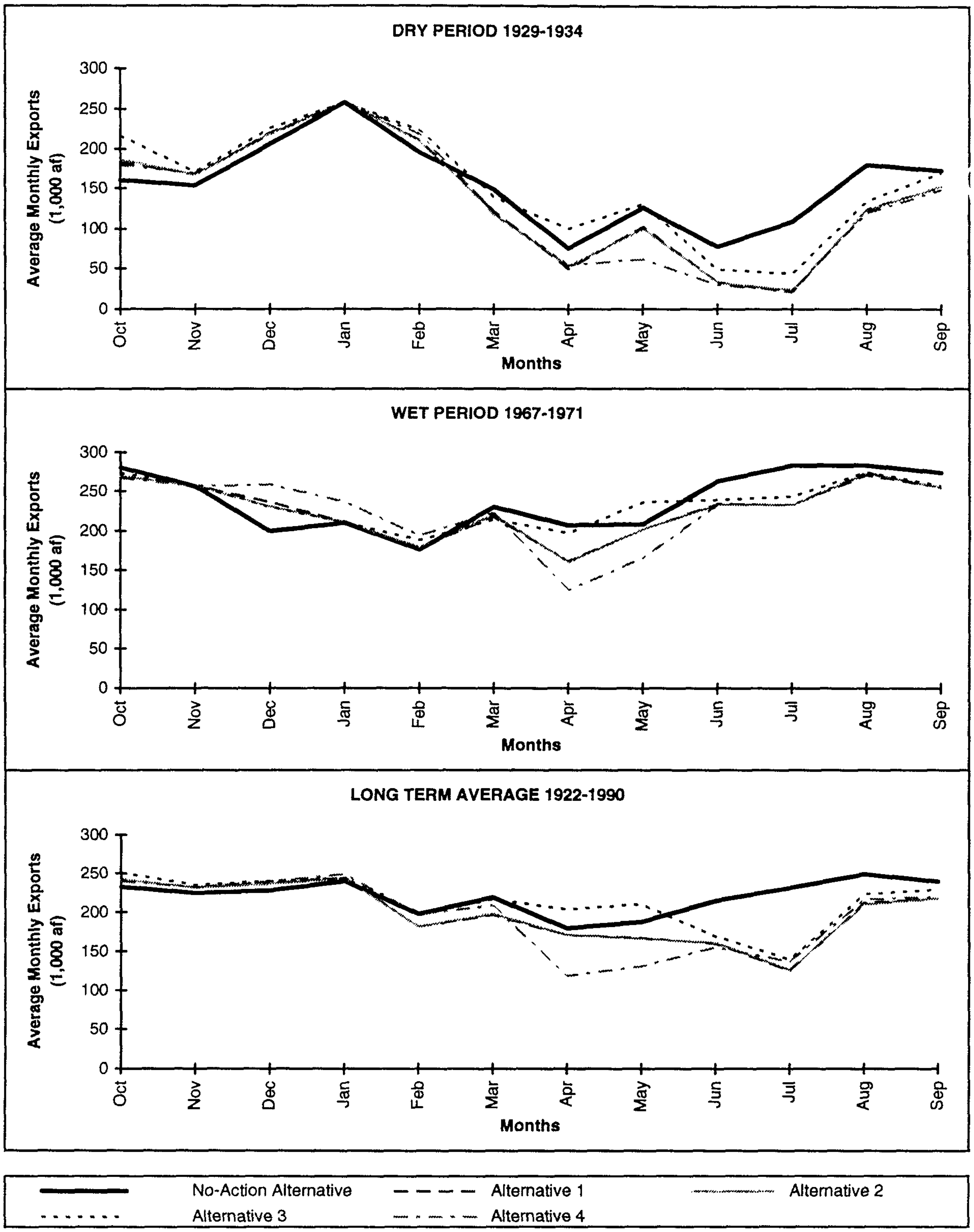


FIGURE III-17

TRACY PUMPING PLANT SIMULATED AVERAGE MONTHLY EXPORTS

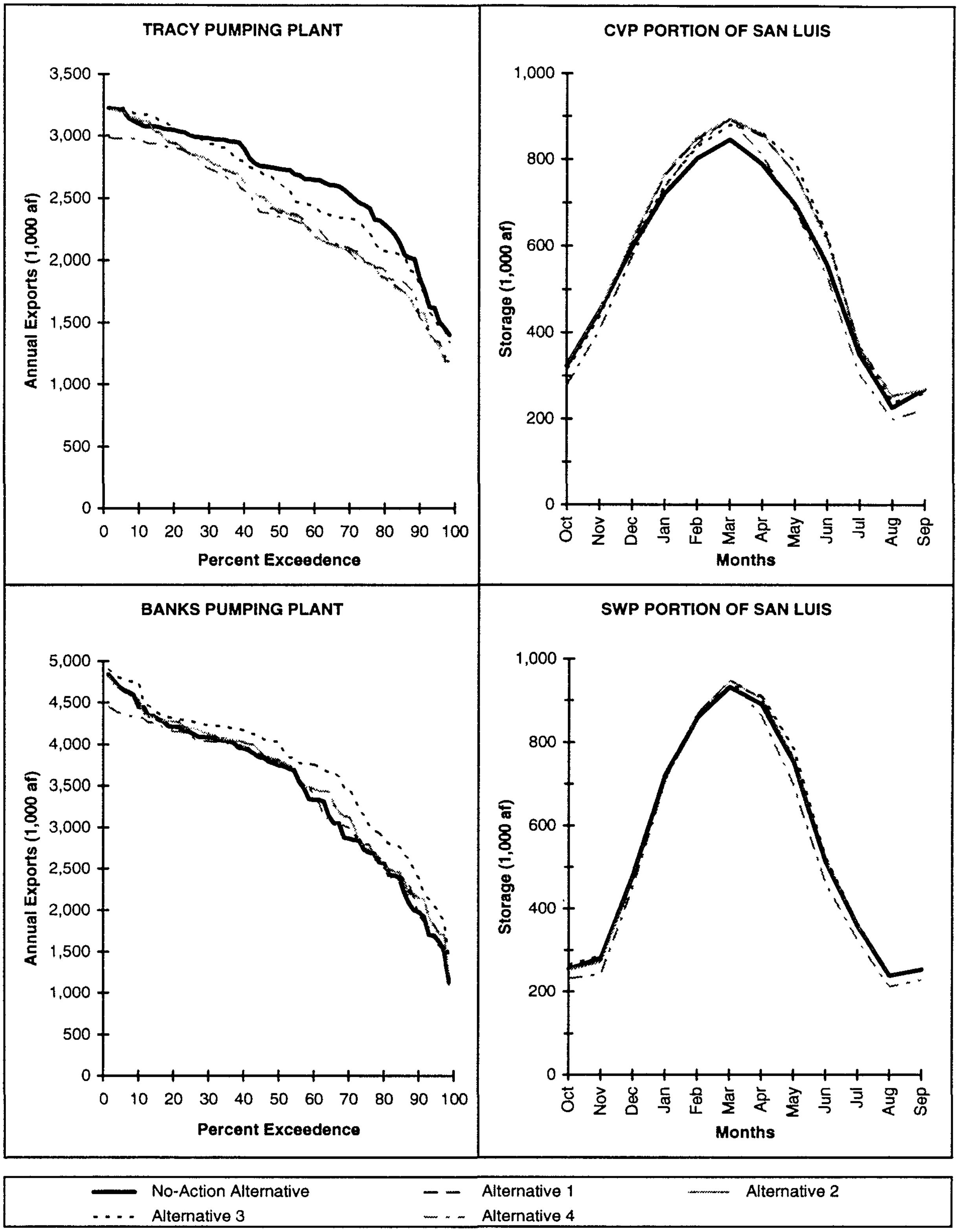


FIGURE III-18
SIMULATED ANNUAL EXPORTS AND SAN LUIS
RESERVOIR AVERAGE END-OF-MONTH STORAGE 1922-1990

In comparison to the No-Action Alternative simulation, average annual Delta outflows in Alternative 1 are reduced by approximately 60,000 acre-feet per year or 0.5 percent. However, the reduction in outflow is small in proportion to the total Delta outflow and cannot be discerned in the average monthly outflow plots shown in Figure III-19 or the monthly time series plots for dry and wet periods shown in Figure III-20. The reduction in average monthly Delta outflow occurs primarily during spring and summer months because of the decrease in Trinity River Basin diversions to the Sacramento River and reduced summer upstream CVP reservoir releases.

West San Joaquin Division. The Alternative 1 impacts to CVP storage in San Luis Reservoir are a direct result of changes in Tracy Pumping Plant monthly exports. As shown in Figure III-18, Alternative 1 average monthly CVP San Luis Reservoir storage levels are higher than in the No-Action Alternative, because of increased October-through-January Tracy Pumping Plant exports. As described above, these increased exports are a result of higher Delta inflows, due to greater upstream CVP reservoir releases to attempt to meet flow targets. Minimum end-of-water year September average monthly storage levels are similar to the No-Action Alternative.

CVP Water Contract Deliveries

This section describes potential changes to CVP water contract deliveries in Alternative 1, as compared to the No-Action Alternative, because of use of (b)(2) water toward meeting the target flows, firm Level 2 refuge deliveries, and increased instream Trinity River fishery flows. The discussion includes CVP deliveries to Sacramento River Water Rights Contractors, San Joaquin River Exchange Contractors, refuges, and Agricultural and M&I Water Service Contractors north and south of the Delta. This section is divided into deliveries north of the Delta, deliveries south of the Delta, and refuge deliveries.

CVP Water Deliveries North of the Delta. CVP deliveries north of the Delta include deliveries to Sacramento River Water Rights Contractors and to Agricultural and M&I Water Service Contractors. CVP deliveries to Sacramento River Water Rights Contractors do not change in Alternative 1 because their delivery deficiencies are based on the Shasta Criteria. The Shasta Criteria is a function of Shasta Lake inflow, which does not change among the Draft PEIS alternatives. Deliveries to Agricultural and M&I Water Service Contractors north of the Delta are a function of CVP available water supply. As available water supply is reduced by the use of (b)(2) water, increased firm Level 2 refuge water supplies, and decreased diversions from the Trinity River Basin, there is a resulting decrease in water service contract deliveries.

Figure III-21 shows the decrease in simulated annual total deliveries to agricultural contractors north of the Delta, including water rights and water service contractors. The frequency distribution for the percent of full delivery to CVP Agricultural Water Service Contractors north of the Delta is presented in Figure III-22. The figure generally shows a 5 to 10 percent reduction in the frequency of deliveries across all delivery levels, with the minimum delivery dropping from about 15 to 0 percent of full contract amount.

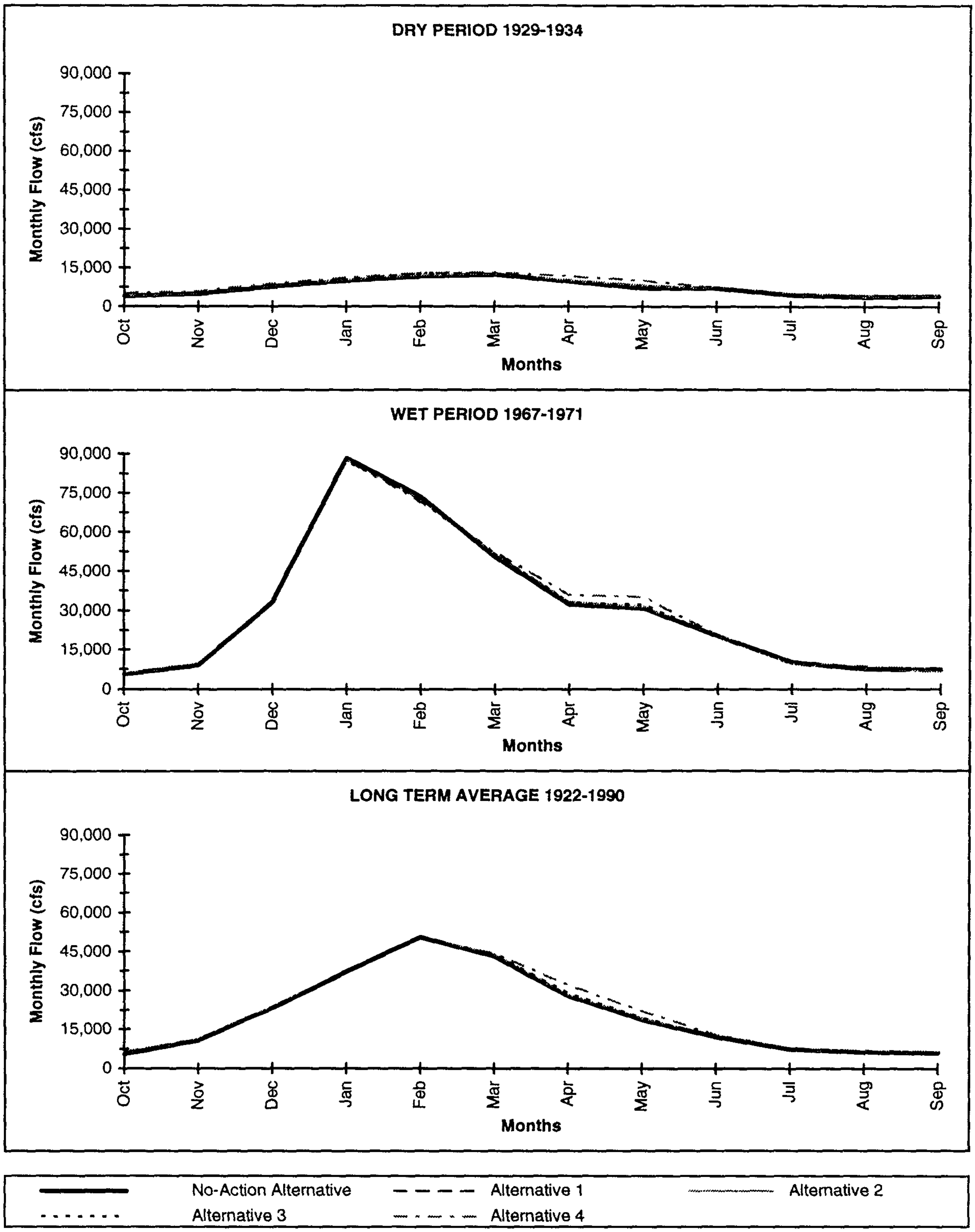


FIGURE III-19

DELTA OUTFLOW SIMULATED AVERAGE MONTHLY FLOWS

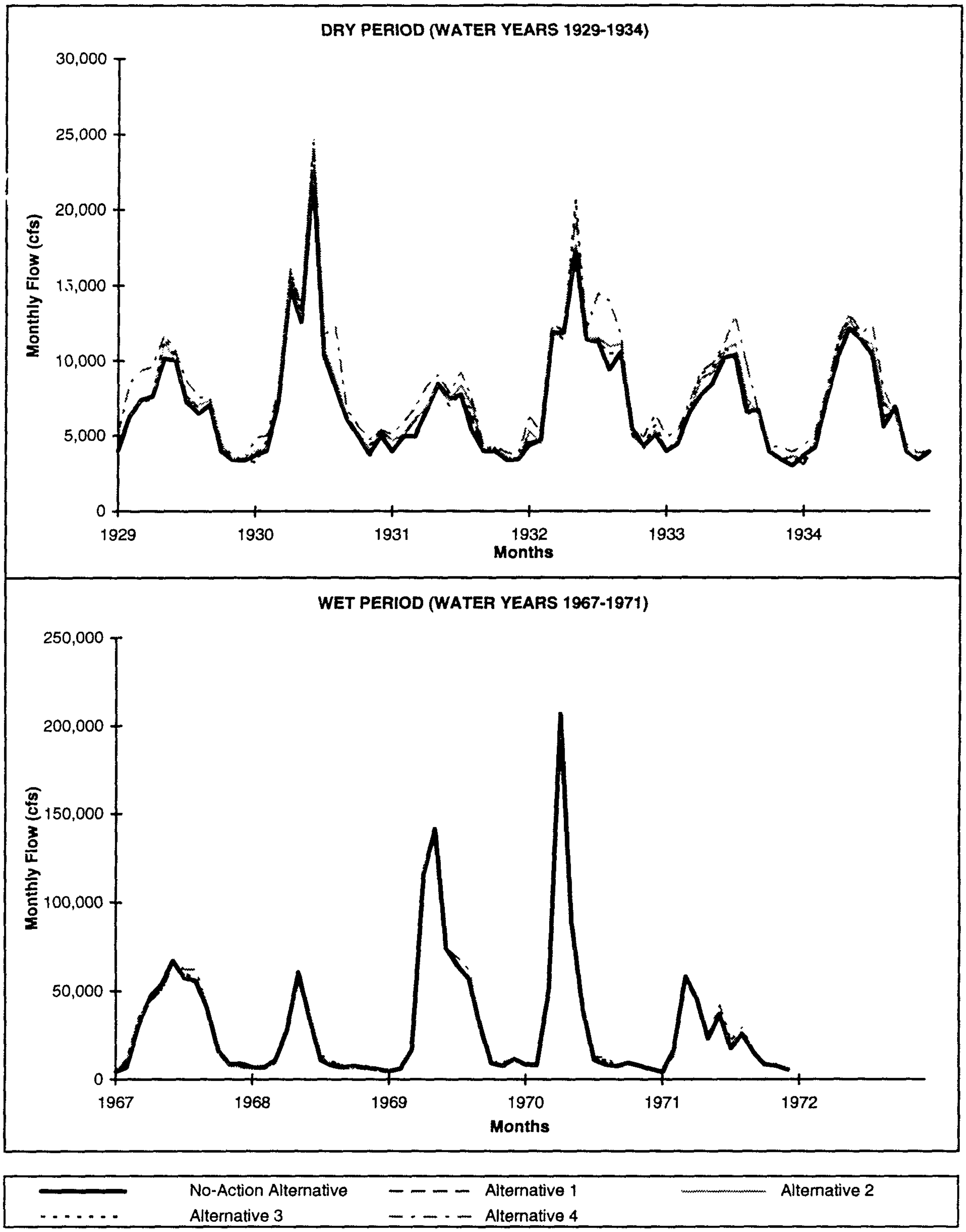
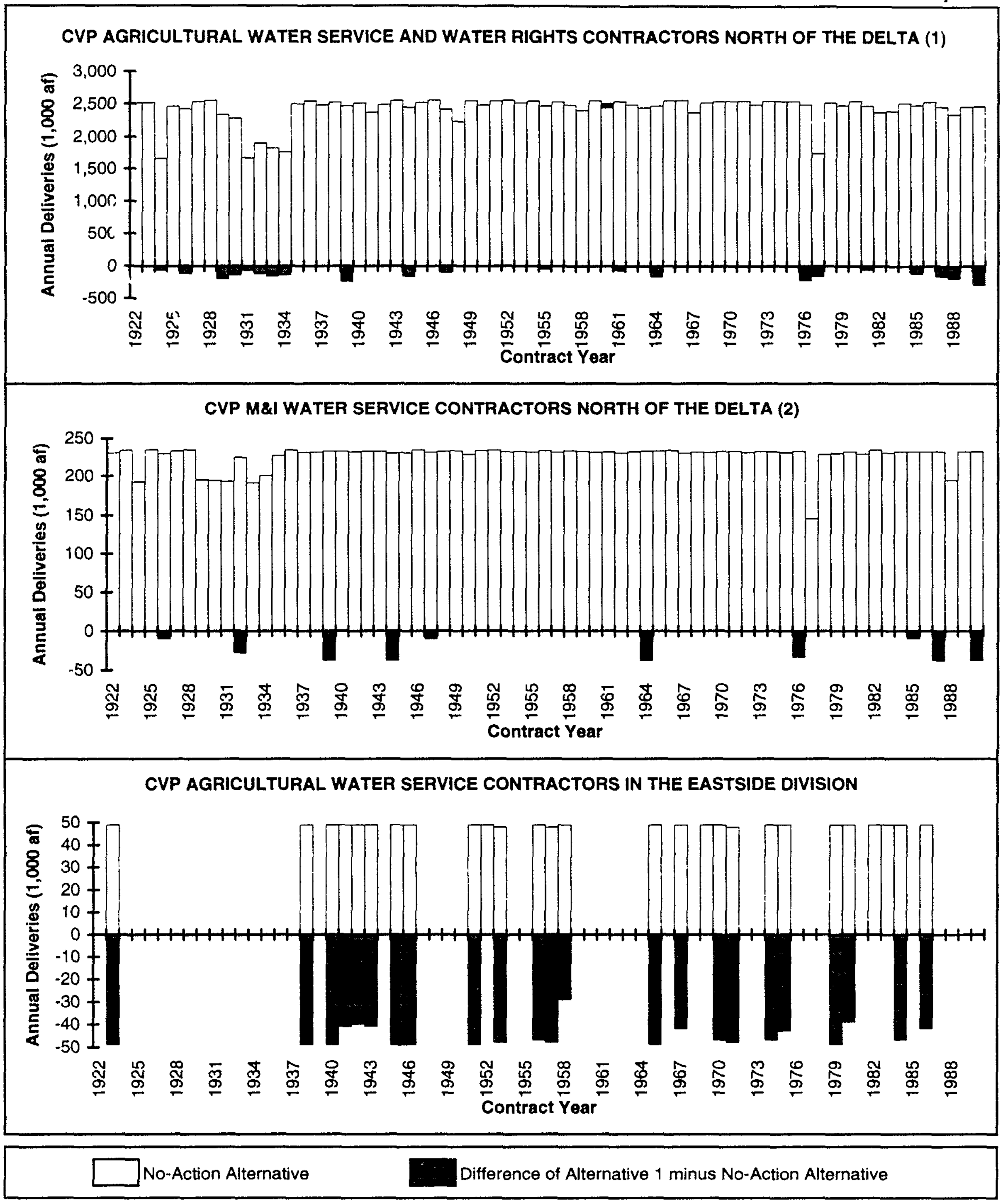


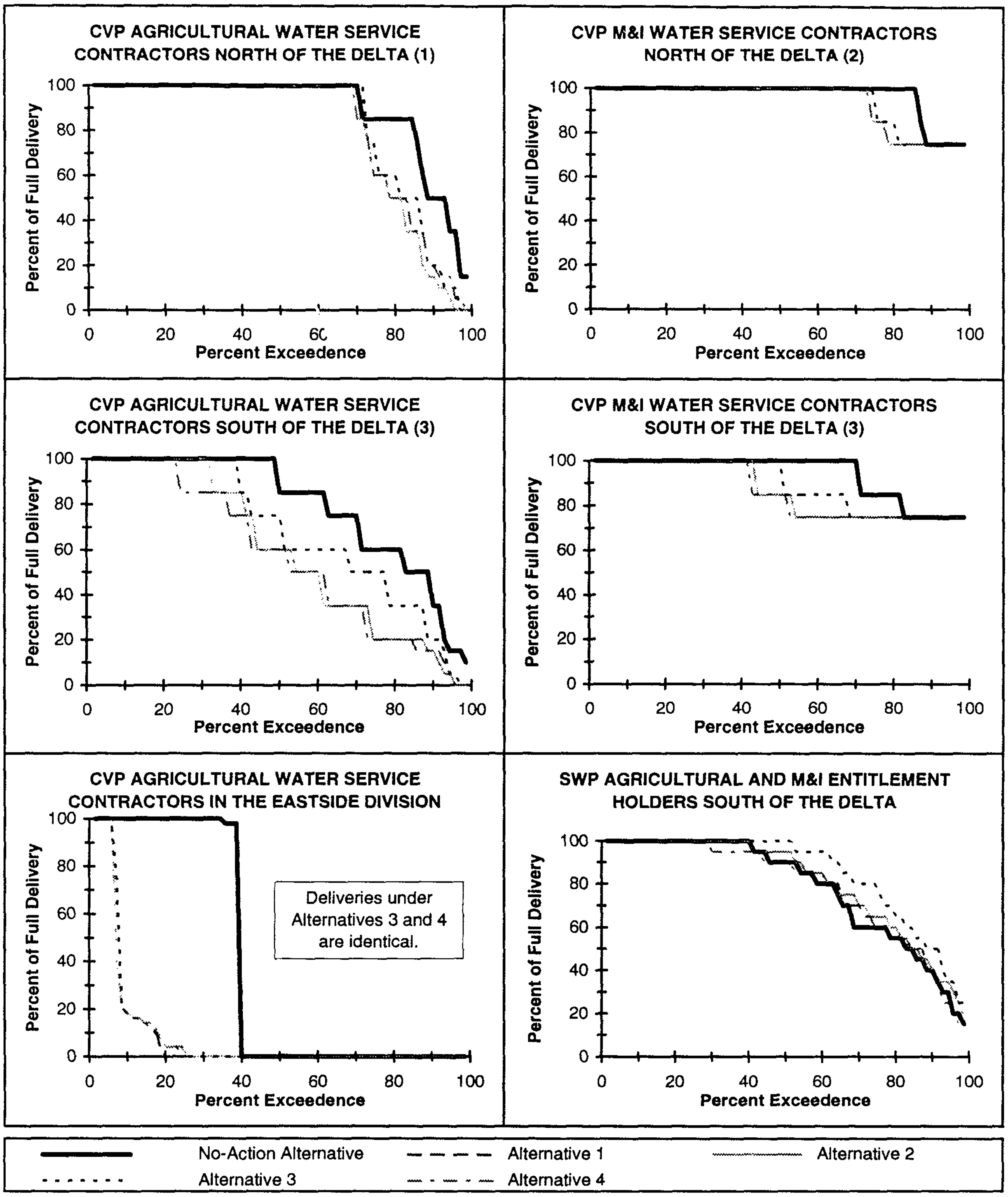
FIGURE III-20

DELTA OUTFLOW SIMULATED MONTHLY FLOWS



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-21
SIMULATED ALTERNATIVE 1 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.
(3) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-22
SIMULATED FREQUENCY OF PERCENT OF FULL ANNUAL DELIVERIES 1922-1990

The reduction in Alternative 1 annual deliveries to M&I Water Service Contractors north of the Delta is shown in Figure III-21. The minimum delivery to M&I Water Service Contractors is limited to 75 percent of the contract amount, as shown in the frequency distribution in Figure II-22. The minimum delivery is made in 15 percent of the years in the No-Action Alternative and 45 percent of the years in Alternative 1. The only exception occurs on the American River in 1977, when all M&I contract and water rights deliveries from the river are reduced below 75 percent in the No-Action Alternative and Alternative 1. The figure shows that full M&I deliveries are reduced from 85 to 70 percent of the years in the 69-year simulation period.

CVP Deliveries in the Eastside Division. As described in Chapter II of the Draft PEIS, two types of long-term CVP Agricultural Water Service Contracts exist for water from the Stanislaus River. These long-term contracts are based on either firm or interim water supplies. In the simulation of Stanislaus River operations for the Draft PEIS, the portion of long-term CVP agricultural water service contracts based on a firm water supply is a direct demand on New Melones Reservoir, and is subject to deficiency criteria based on reservoir storage and projected inflow. The portion of the total long-term CVP agricultural water service contract amount based on an interim water supply would be delivered on an "as available" basis in the Draft PEIS analysis, and is assessed based on the availability and occurrence of flood control releases from New Melones Reservoir.

Simulated annual deliveries to Agricultural Water Service Contractors from the Stanislaus River for the No-Action Alternative and Alternative 1 are compared in Figure III-21. As shown in this figure, water service contract deliveries based on a firm water supply would be reduced or eliminated in many years of the simulation period as a result of (b)(2) Water Management in Alternative 1. A frequency distribution of these deliveries, shown in Figure III-22, reveals that partial or full deliveries would be made in approximately 10 to 20 percent of the years in Alternative 1, as compared to approximately 40 percent of the years under the No-Action Alternative. Similarly, the opportunity for delivery pursuant to contracts based on an interim water supply would be reduced in Alternative 1 as compared to the No-Action Alternative. In the No-Action Alternative, partial or full deliveries of contract amounts based on an interim water supply could be provided in 10 percent of the simulated years, and partial delivery could occur in up to 40 percent of the years.

As a result of (b)(2) Water Management in Alternative 1, end of September storage levels in New Melones Reservoir would be lowered, as shown in Figure III-2. This would reduce the frequency of flood control releases, and would therefore affect the opportunity for deliveries to CVP contracts based on an interim water supply. Under Alternative 1, the opportunity for full or partial delivery to CVP contracts based on an interim water supply would be reduced to approximately 10 percent of the simulated years.

CVP Water Deliveries South of the Delta. CVP deliveries south of the Delta include deliveries to San Joaquin River Exchange Contractors, and Agricultural and M&I Water Service Contractors. CVP deliveries to San Joaquin River Exchange Contractors do not change in Alternative 1 because their delivery deficiencies are based on the Shasta Criteria. The Shasta Criteria is a function of Shasta Lake inflow, which does not change between the Draft PEIS alternatives and the No-Action Alternative. Deliveries to Agricultural and M&I Water Service Contractors south of the Delta are a function of available CVP water supply and the amount of water that can be exported through Tracy Pumping Plant.

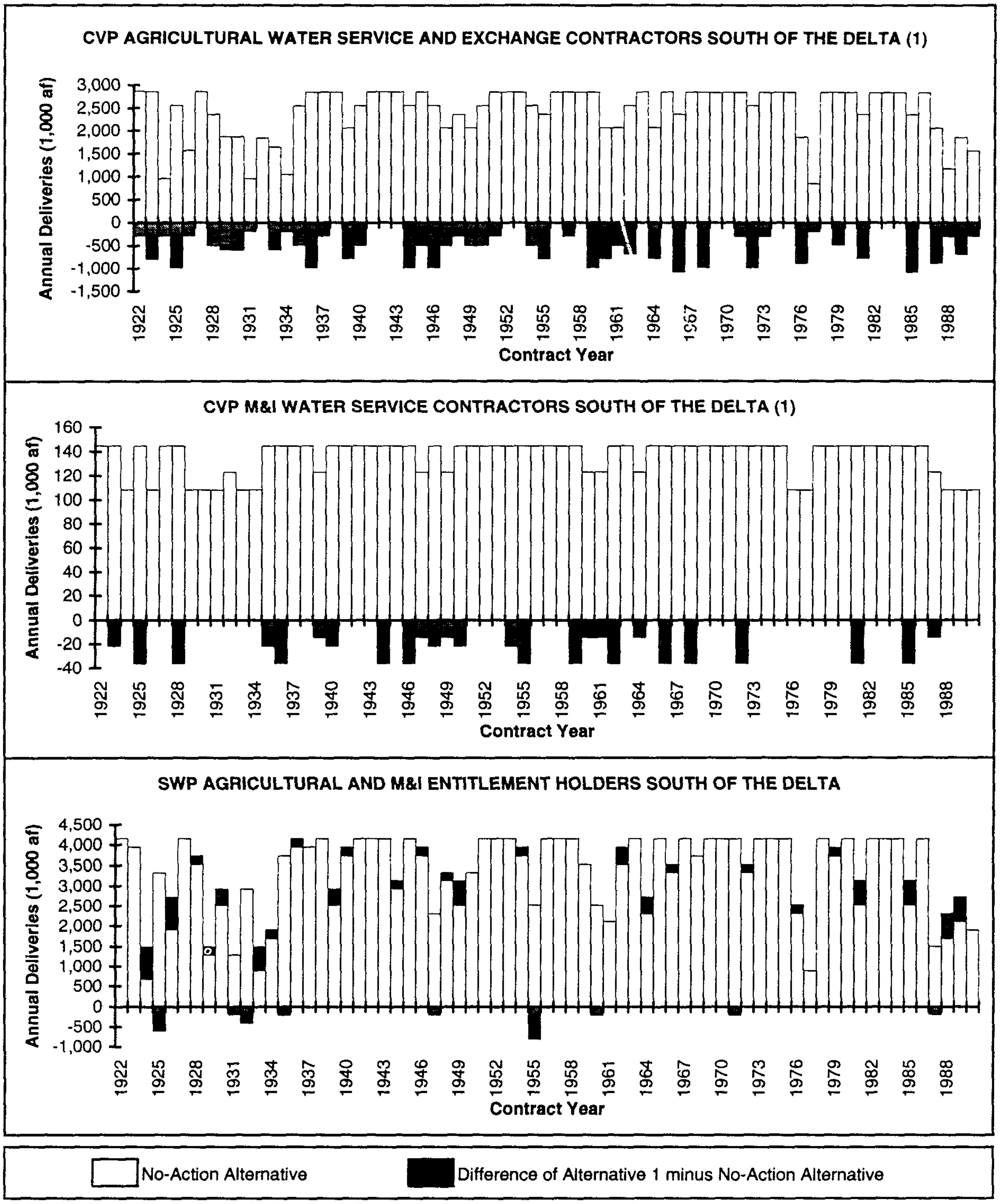
Figure III-23 shows the decrease in simulated annual total deliveries to agricultural contractors south of the Delta, including exchange and water service contractors. The frequency distribution for the percent of full delivery to CVP Agricultural Water Service Contractors south of the Delta is presented in Figure III-22. The figure generally shows a 20 to 30 percent reduction in the frequency of deliveries across all delivery levels, with the minimum delivery dropping from about 10 to 0 percent of full contract amount.

The reduction in Alternative 1 annual deliveries to M&I Water Service Contractors south of the Delta is shown in Figure III-23. The minimum delivery to M&I Water Service Contractors is limited to 75 percent of the contract amount, as shown in the frequency distribution in Figure III-22. The minimum delivery is made in 20 percent of the years in the No-Action Alternative and about 50 percent of the years in Alternative 1. The figure shows that full M&I deliveries are reduced from 70 to 40 percent of the years in the 69-year simulation period.

CVP Water Deliveries To Refuges. Alternative 1 includes delivery of firm Level 2 water supplies to refuges. Figure III-24 shows the increase of about 180,000 acre-feet per year in Alternative 1 annual refuge deliveries as compared to the No-Action Alternative. The 25 percent deficiency to refuge deliveries in critical dry years is based on the Shasta Criteria, as it is in the No-Action Alternative.

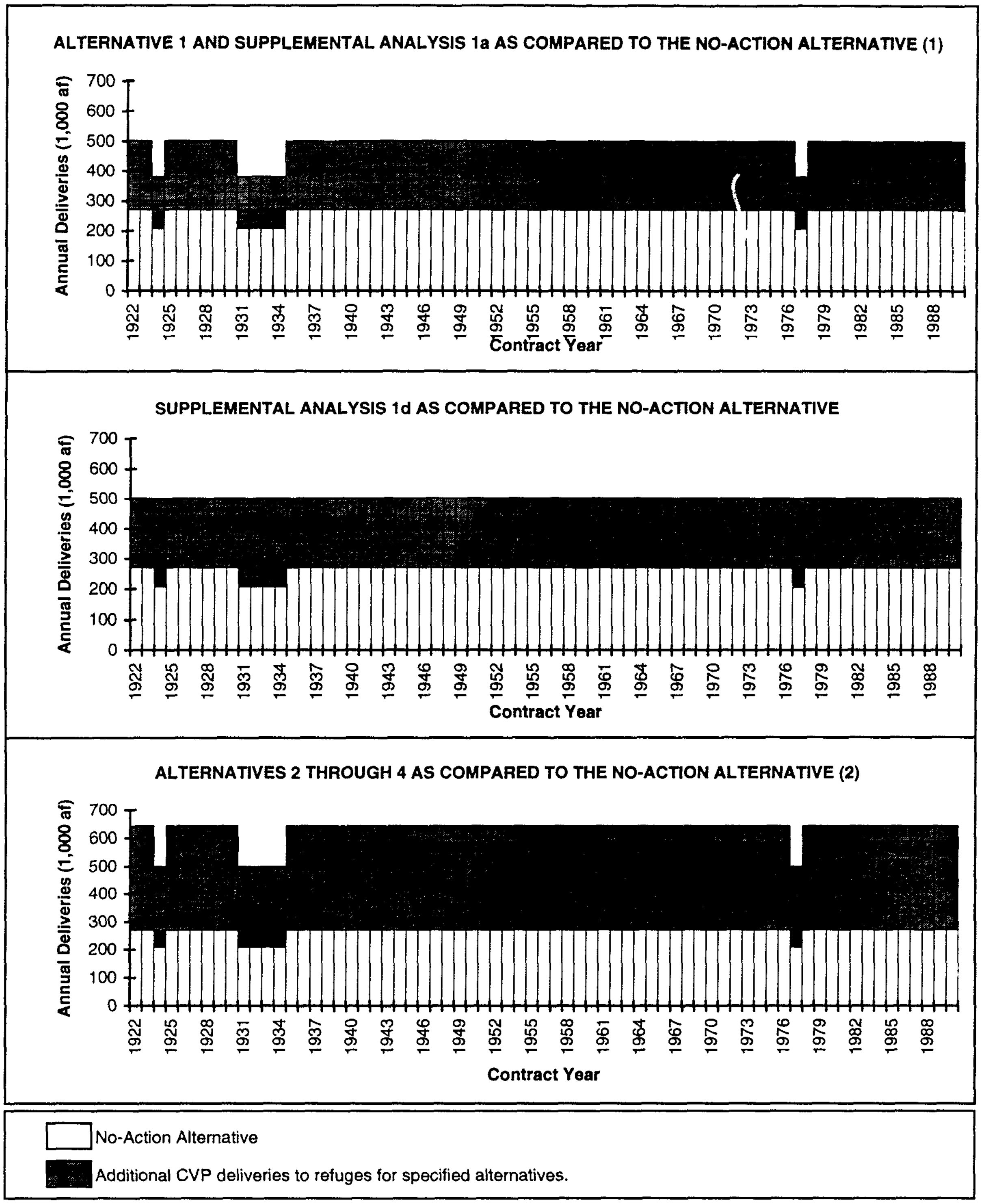
ALTERNATIVE 1 IMPACTS ON SWP OPERATIONS AND DELIVERIES

This section provides a comparison of Alternative 1 and No-Action Alternative SWP reservoir operations, resulting river flows, and water deliveries to SWP contractors. Deliveries to SWP contractors in the Alternative 1 simulation, as compared to deliveries in the No-Action Alternative simulation, are shown in Table III-5.



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-23
SIMULATED ALTERNATIVE 1 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTES: (1) Refuge deliveries under Supplemental Analysis 1a are identical to Alternative 1.
(2) Refuge deliveries under Alternatives 3 and 4 are identical to Alternative 2.

FIGURE III-24

SIMULATED CVP ANNUAL REFUGE DELIVERIES 1922-1990

TABLE III-5
COMPARISON OF SWP DELIVERIES IN THE ALTERNATIVE 1 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual SWP Deliveries (1,000 acre-feet)		Average Annual Change in SWP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 1	
1922 - 1990	Simulation Period	3,330	3,430	+100
1928 - 1934	Dry Period	2,050	2,200	+150
1967 - 1971	Wet Period	4,140	4,100	-40

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

SWP Operations

SWP operations are affected by the changes in seasonal releases from upstream CVP reservoirs for target flows. These changes to CVP operations shift the timing of flow entering the Delta, and affect the SWP responsibility to help meet in-basin water rights and Delta water quality requirements under the COA.

Lake Oroville and Feather River Operations. Small differences in SWP Lake Oroville operations are the result of changes in response to the availability of excess water in the Delta, as a function of (b)(2) Water Management and reduced diversions from the Trinity River Basin. These changes in water availability require different Lake Oroville releases to meet COA obligations and/or Delta water quality requirements. Figure III-2 shows a comparison of the frequency distributions for Lake Oroville end-of-water year storage for Alternative 1 and the No-Action Alternative.

Simulated average monthly flows in the Feather River below Nicolaus in the No-Action Alternative and Alternative 1 are presented in Figure III-25 for dry, wet, and 69-year simulation periods. The small differences in the flows reflect decreased fall and increased summer upstream Lake Oroville releases in response to Delta needs. However, the changes in flow are small in proportion to total flows at Nicolaus. Figure III-26 shows a comparison of simulated monthly flows for the dry period 1929 through 1934 and the wet period 1967 though 1972.

Delta Operations. In Alternative 1 Delta inflows are increased during fall and winter months because of greater upstream CVP reservoir releases for target flows. In many years, the additional fall and winter Delta inflow exceeds the pumping capacity of the CVP Tracy Pumping Plant. When this occurs, the SWP has the potential to increase Banks Pumping Plant exports to take advantage of the excess water, or pump at capacity while reducing upstream releases from

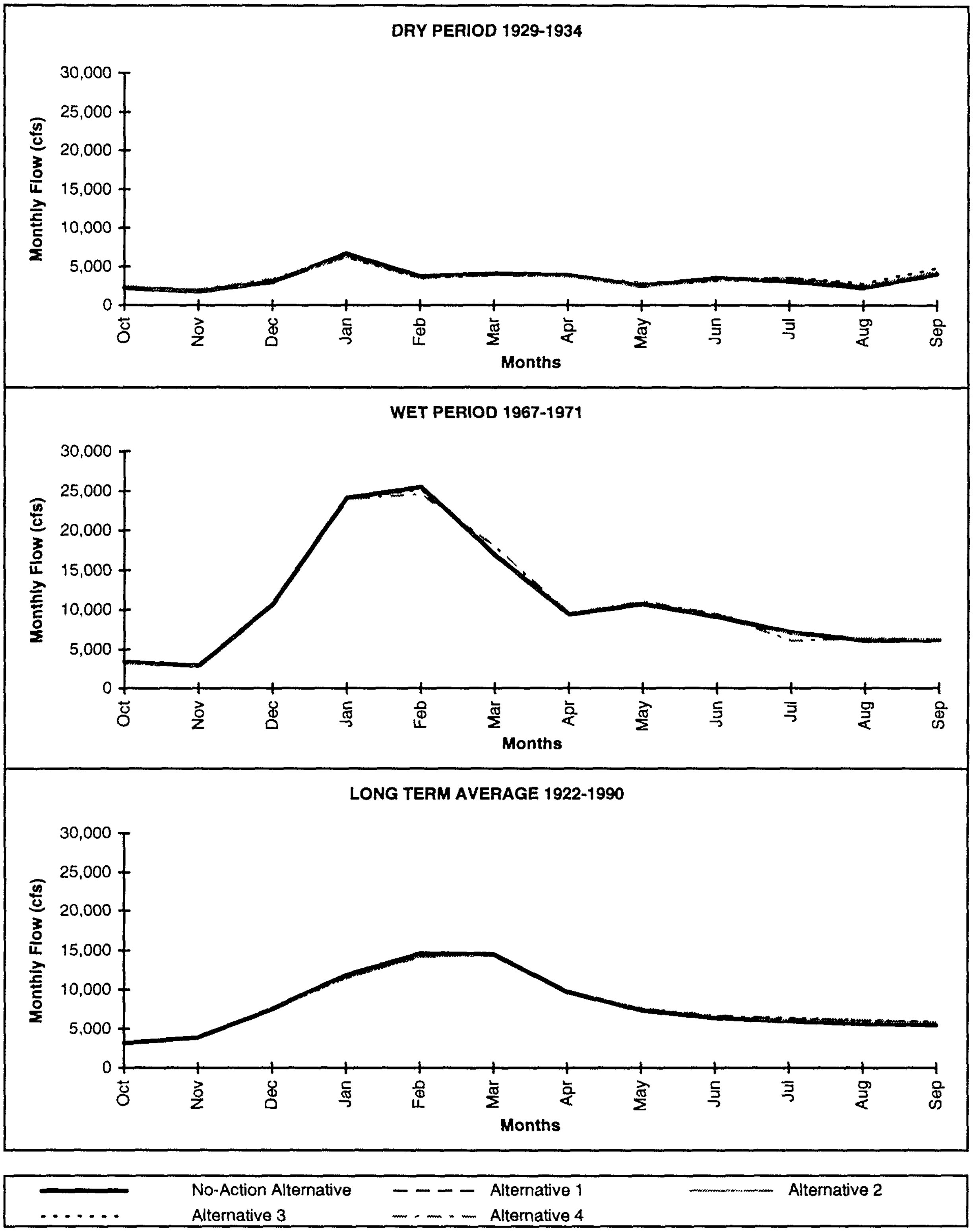


FIGURE III-25

FEATHER RIVER AT NICOLAUS SIMULATED AVERAGE MONTHLY FLOWS

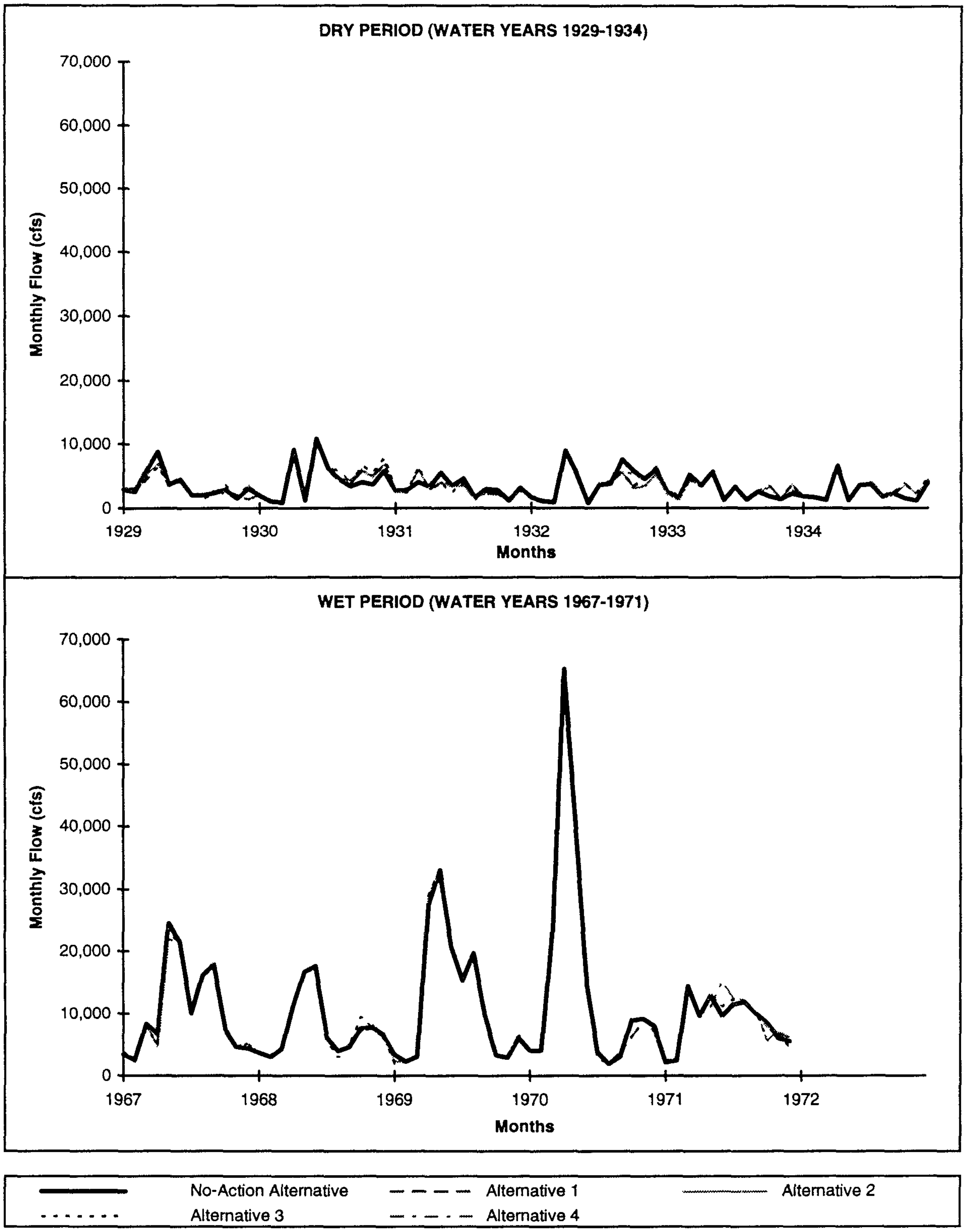


FIGURE III-26

FEATHER RIVER AT NICOLAUS SIMULATED MONTHLY FLOWS

Lake Oroville. Lake Oroville releases can then be increased in the summer for delivery purposes. Frequency distributions of simulated annual exports through Banks Pumping Plant in the No-Action Alternative and Alternative 1 simulations are compared in Figure III-18. In comparison to the No-Action Alternative, the average annual increase in SWP exports is about 70,000 acre-feet per year. Figure III-27 shows a comparison of average monthly Banks exports for the dry, wet, and 69-year simulation period.

It is possible that a portion of the water pumped at the Banks Pumping Plant would be wheeled by the SWP for delivery to CVP Cross Valley Canal contractors.

San Luis Reservoir Operations. The Alternative 1 impacts to SWP storage in San Luis Reservoir are a direct result of changes in Banks Pumping Plant monthly exports. As shown in Figure III-18, Alternative 1 average monthly SWP San Luis Reservoir storage levels are slightly higher than in the No-Action Alternative, a result of increased October-through-January Banks Pumping Plant exports. Minimum end-of-water year September average monthly storage levels are similar to the No-Action Alternative.

SWP Entitlement Water Deliveries

In Alternative 1 SWP deliveries to agricultural and M&I entitlement holders south of the Delta increase about 100,000 acre-feet per year on an average annual basis. A comparison of frequency distributions for the simulated percent of full contract delivery in the No-Action Alternative and Alternative 1 is presented in Figure III-22. The difference in simulated annual deliveries is presented in Figure III-23. The increase in SWP deliveries in Alternative 1 because of the SWP's ability to adjust operations to take advantage of excess Delta inflows resulting from increased upstream CVP reservoir releases for target flows. If the SWP contracted with CVP water users to wheel this excess CVP water through Banks Pumping Plant, these increased SWP deliveries might not occur.

SUPPLEMENTAL ANALYSIS 1a

DESCRIPTION OF SUPPLEMENTAL ANALYSIS

As described in the previous section, Alternative 1 includes the use of (b)(2) water to help meet fishery target flow goals on CVP-controlled streams, provides delivery of firm Level 2 water supplies to refuge, and implements the revised instream fishery flow pattern on the Trinity River. In addition, Supplemental Analysis 1a includes the use of (b)(2) water to attempt to meet fishery objectives in the Delta, as well as on CVP-controlled streams. As is the case with Alternative 1, a simplified version of the (b)(2) Water Management in the Delta was developed for the Draft PEIS analysis. The Delta (b)(2) actions evaluated in Supplemental Analysis 1a are based on preliminary actions proposed by the Service in February of 1996. The assumptions and process to develop a (b)(2) Water Management strategy for Supplemental Analysis 1a are discussed in Attachment G-2 of the Draft PEIS.

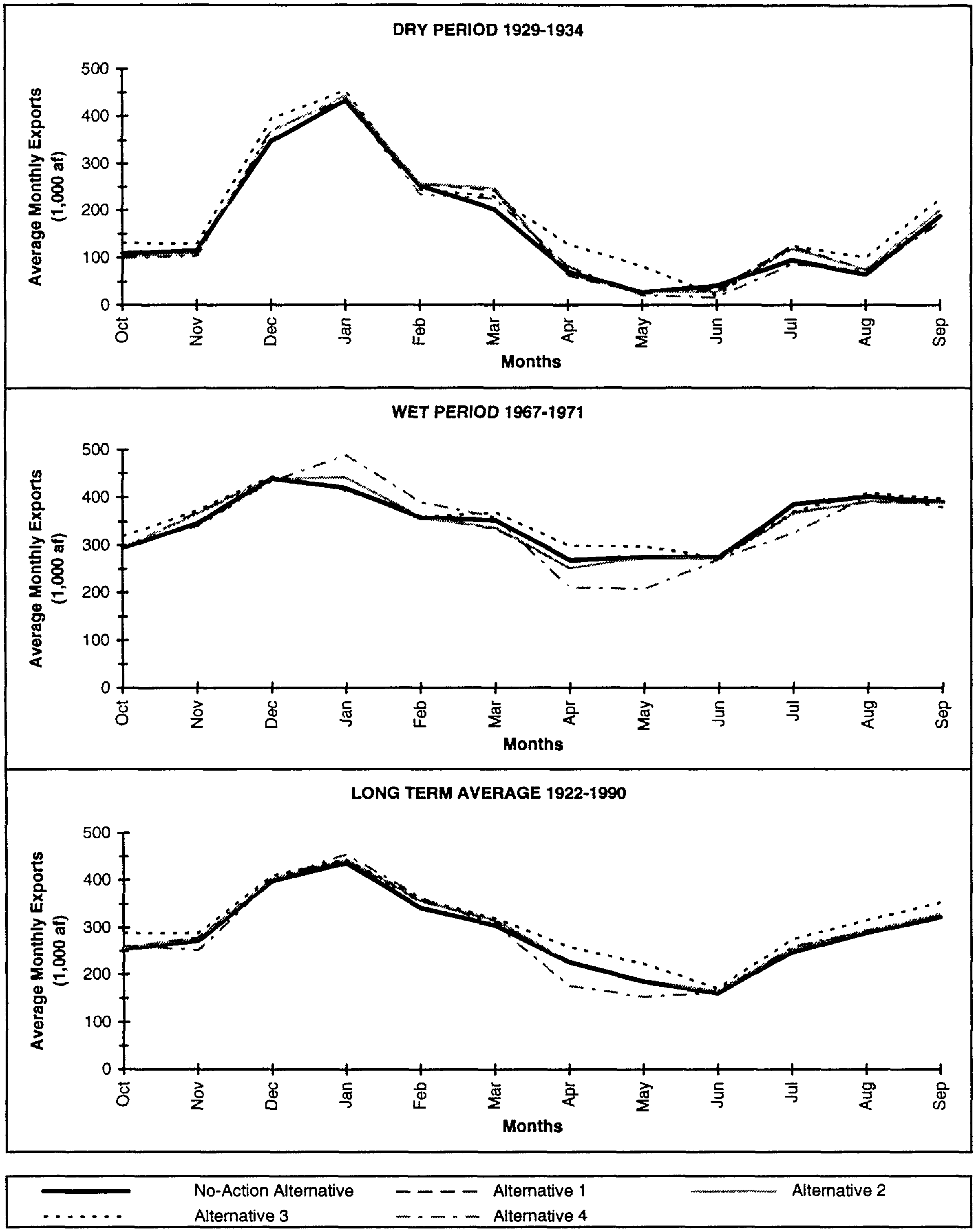


FIGURE III-27

BANKS PUMPING PLANT SIMULATED AVERAGE MONTHLY EXPORTS

The Delta (b)(2) actions incorporated into Supplemental Analysis 1a, in addition to the upstream (b)(2) Water Management described in Alternative 1, are listed below.

- Maintain a 1,500-cfs maximum for total CVP/SWP exports during the 30-day pulse flow period from April 15 through May 15. The 1,500-cfs maximum pumping limit approximates the Service's desired San Joaquin River pulse flow export/inflow ratio under each of the different water year types.

- Increase level of protection targeted by the May and June X2 requirement to a 1962 level of development. This represents an increase in the number of days when X2 (the 2 parts per thousand isohaline) would be required at Chipps Island as specified in Table A of the SWRCB May 1995 Water Quality Control Plan.

- Reduce CVP Tracy Pumping Plant exports in November and December to decrease the fall Delta export/inflow ratio. This action is intended to reduce the direct and indirect entrainment effects of export pumping on migrating juvenile chinook salmon.

SUPPLEMENTAL ANALYSIS 1a IMPACTS ON CVP OPERATIONS AND DELIVERIES

Supplemental Analysis 1a includes all the CVPIA actions in Alternative 1, plus the use of (b)(2) water in the Delta as described above. The Delta (b)(2) actions specified above would reduce the flexibility of the CVP to fill San Luis Reservoir during November and December and would further limit the amount of water that could be exported during the pulse flow period of April 15 to May 15. The simulated delivery impacts of Supplemental Analysis 1a as compared to the No-Action Alternative are shown in Table III-6. A discussion of operational and delivery impacts as compared to the No-Action Alternative is provided below.

CVP Operations

The addition of Delta (b)(2) water use in Supplemental Analysis 1a would have a minor effect on upstream CVP reservoir operations of the Trinity River, Shasta River, Sacramento River, and American River divisions. The (b)(2) Delta actions primarily affect the CVP's ability to export water south of the Delta through Tracy Pumping Plant. Some additional water would also need to be released from upstream reservoirs to meet the increased number of X2 days specified at Chipps Island. A summary of the impacts to each of the CVP divisions is provided below.

TABLE III-6
COMPARISON OF CVP DELIVERIES IN SUPPLEMENTAL ANALYSIS 1a, ALTERNATIVE 1, AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet)			Alternative 1a and No-Action Alternative:
		No-Action Alternative	Alternative 1	Supplemental Analysis 1a	Average Annual Change in CVP Deliveries (1,000 acre-feet)
1922 - 1990	Simulation Period	5,770	5,300	5,200	-570
1928 - 1934	Dry Period	4,560	4,050	3,980	-580
1967 - 1971	Wet Period	6,310	6,020	5,970	-340

NOTES:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.

Trinity River Division. As shown in Figures III-28 and III-29, the simulated operations of Clair Engle Lake and the releases into Clear Creek from Whiskeytown Lake to meet target flows are similar to those in Alternative 1.

Shasta and Sacramento River Divisions. As in the Trinity River Division, the simulated Shasta Lake operations and the resulting average monthly flows on the Sacramento River at Keswick and Sacramento River at Knights Landing are the same as in Alternative 1. Figures III-28, III-30, and III-31 show there is virtually no discernable change to simulated CVP operations.

American River Division. The frequency distribution for simulated Folsom Lake end-of water-year storage in Figure III-28 and the monthly flows shown in Figure III-32 for the American River below Nimbus are similar to Alternative 1.

Eastside Division. Supplemental Analysis 1a includes no actions that would change operations of New Melones Reservoir or flows in the Stanislaus River below Goodwin Dam as compared to Alternative 1, as shown in Figures III-28 and III-33. Similarly, flows and water quality conditions on the San Joaquin River at Vernalis would be similar to conditions under Alternative 1, as shown in Figures III-34 and III-35.

Delta Division. The Delta (b)(2) actions in Supplemental Analysis 1a would have a direct impact on CVP Tracy Pumping Plant exports. The frequency distribution in Figure III-36 shows the reduction in simulated annual exports, as compared to Alternative 1 and the No-Action Alternative, over the 69-year simulation period. Figure III-37 shows the shift in average monthly Tracy Pumping Plant exports for the dry, wet, and simulation periods. The figure shows the

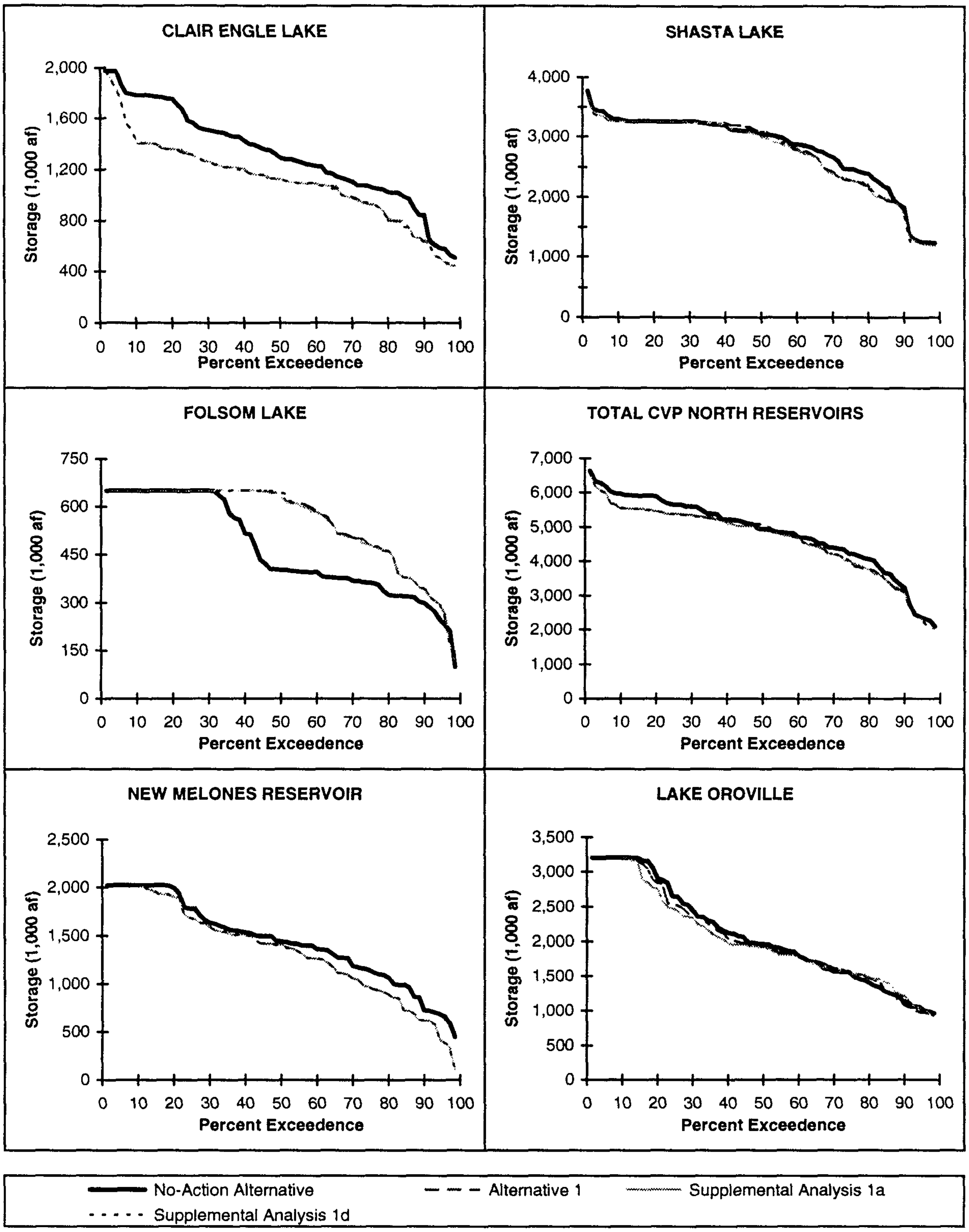


FIGURE III-28

SIMULATED FREQUENCY OF END-OF-WATER YEAR STORAGE 1922-1990

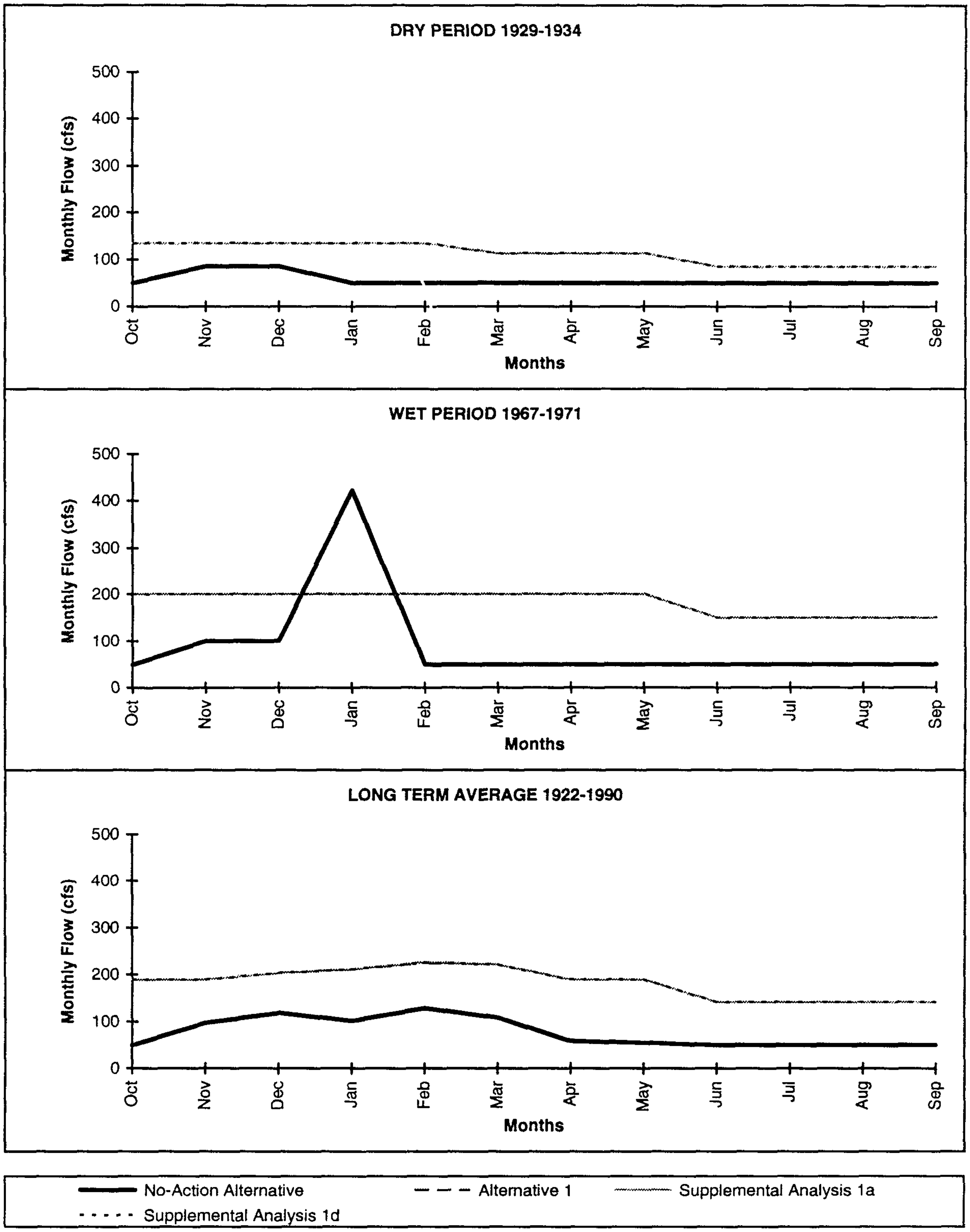


FIGURE III-29
CLEAR CREEK BELOW WHISKEYTOWN
SIMULATED AVERAGE MONTHLY FLOWS

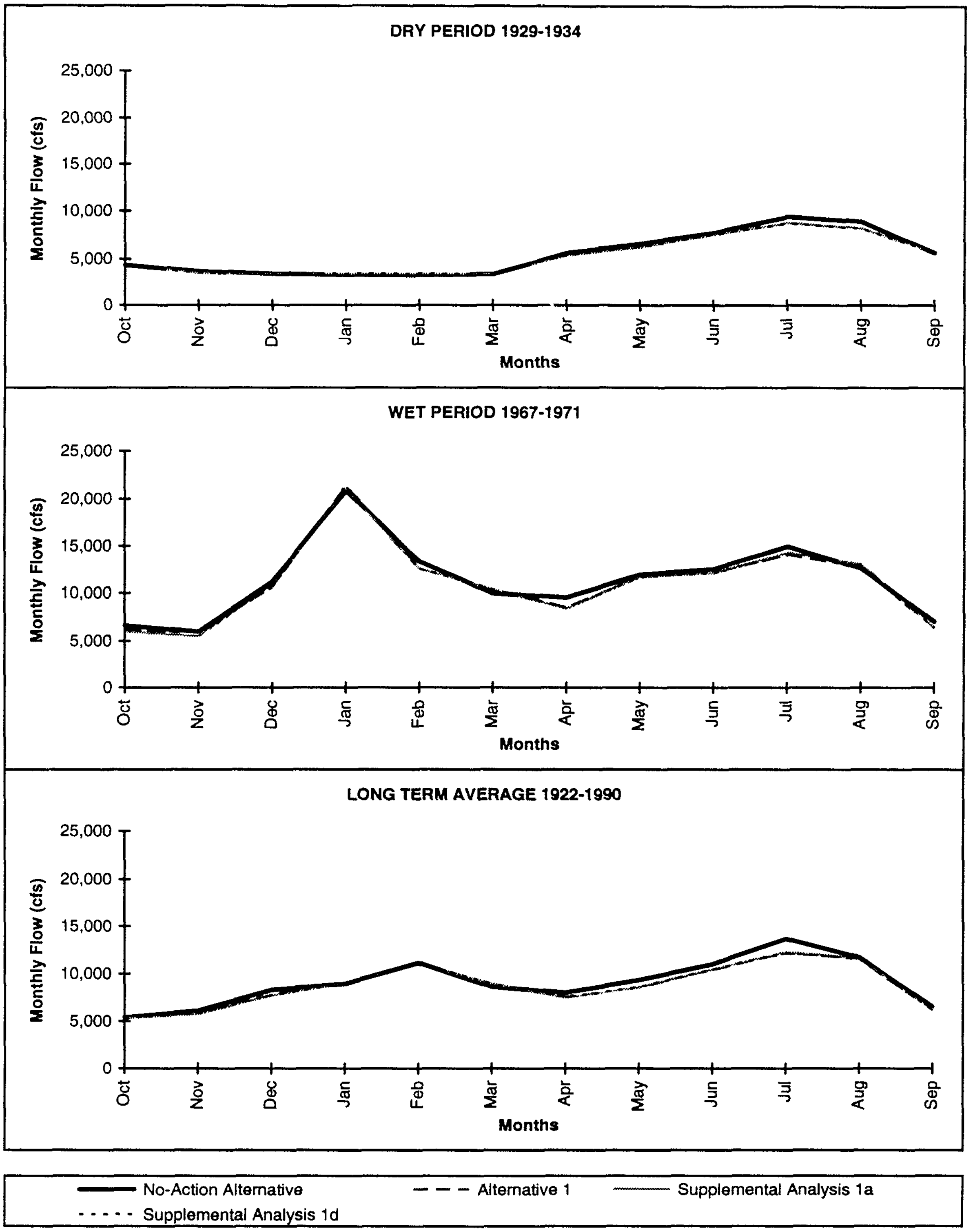


FIGURE III-30
SACRAMENTO RIVER AT KESWICK
SIMULATED AVERAGE MONTHLY FLOWS

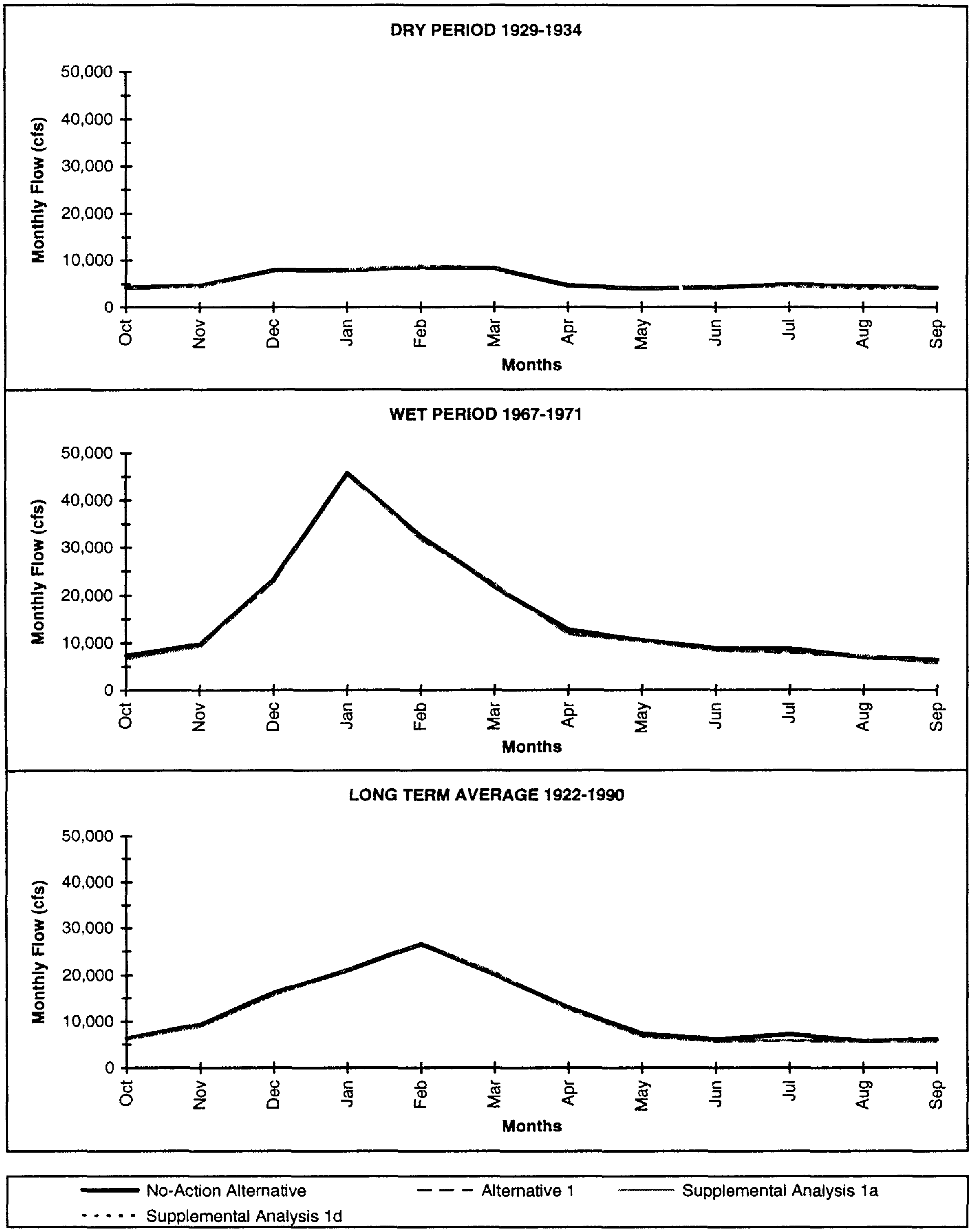


FIGURE III-31
SACRAMENTO RIVER AT KNIGHTS LANDING
SIMULATED AVERAGE MONTHLY FLOWS

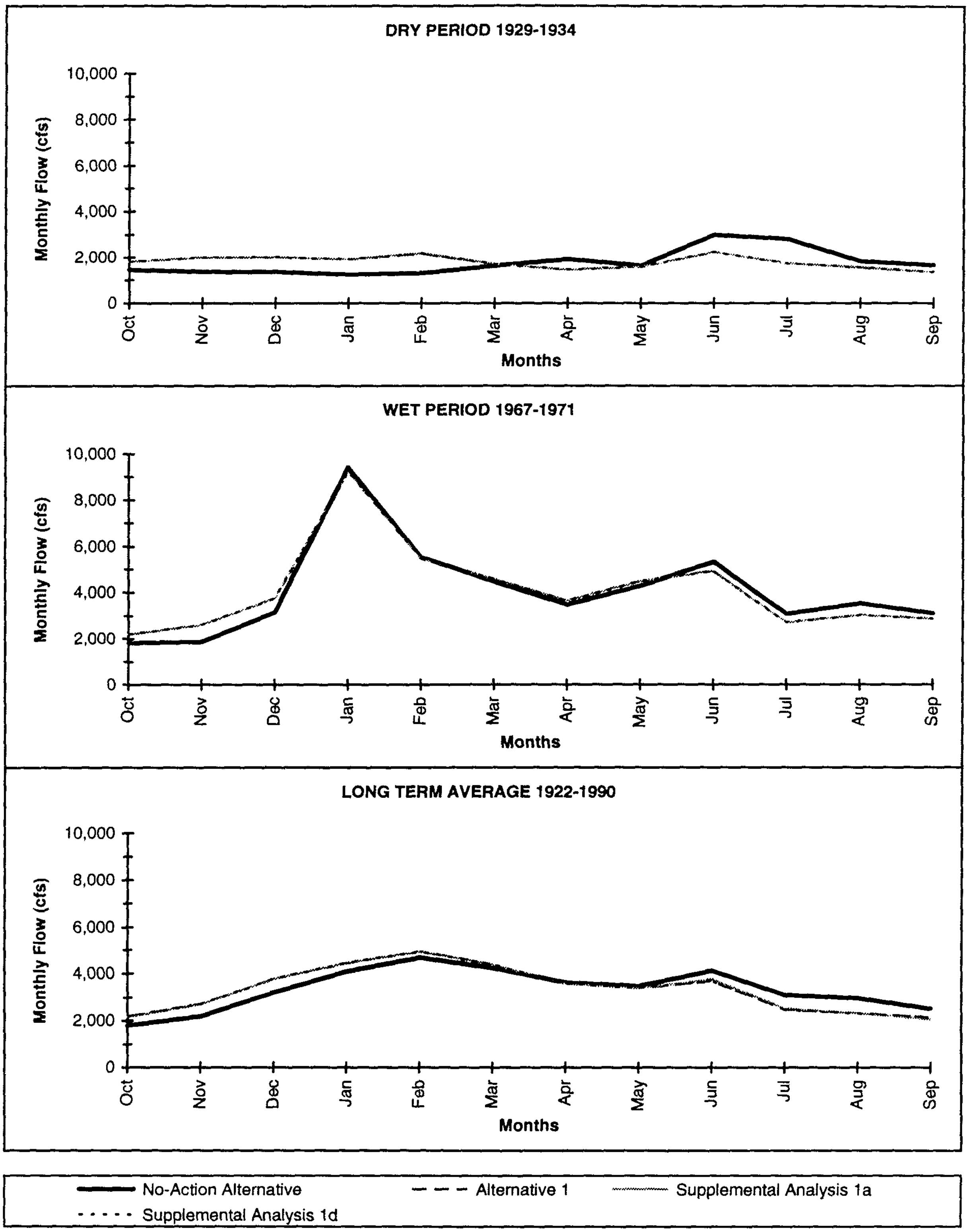


FIGURE III-32

AMERICAN RIVER BELOW NIMBUS SIMULATED AVERAGE MONTHLY FLOWS

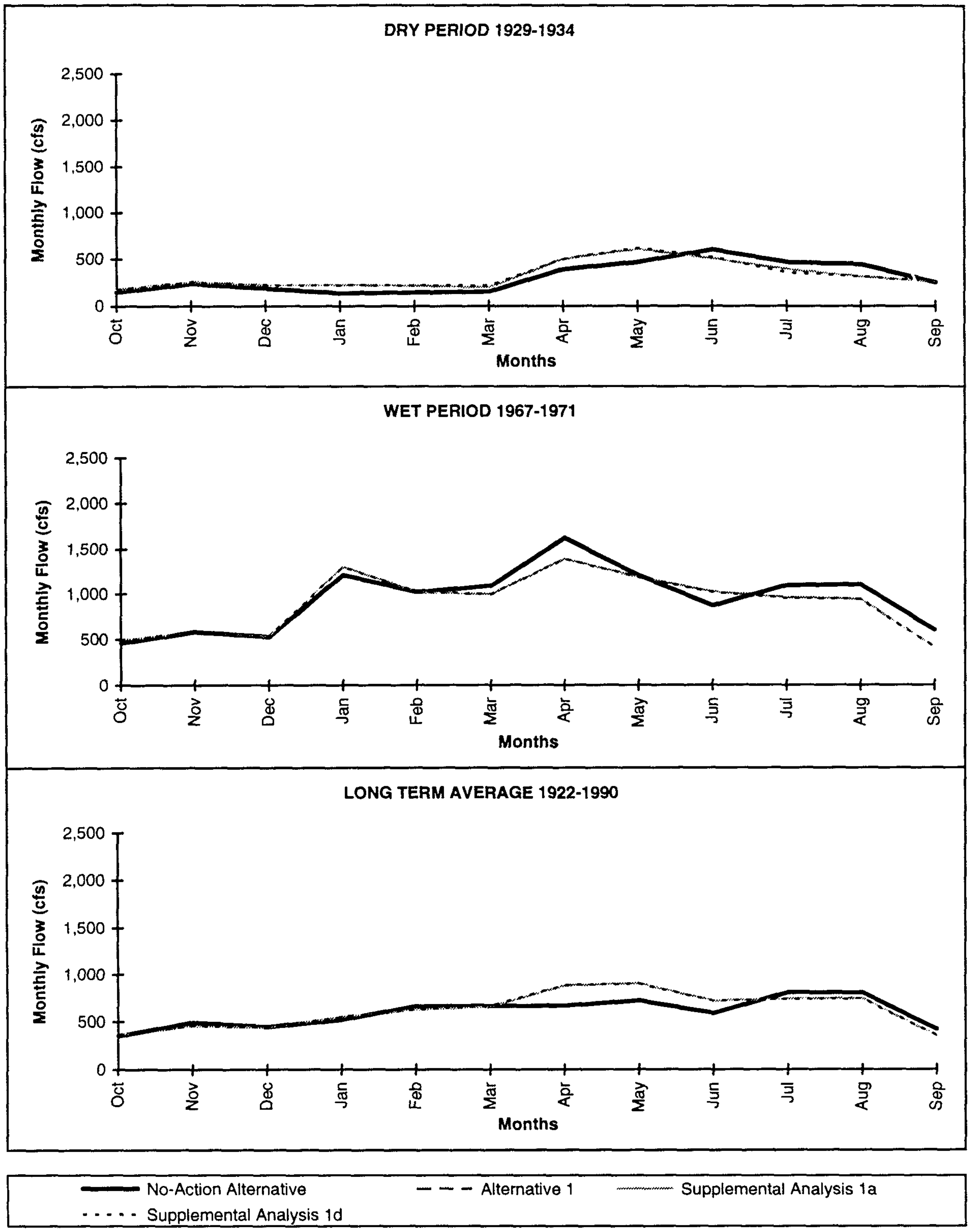


FIGURE III-33
STANISLAUS RIVER BELOW GOODWIN
SIMULATED AVERAGE MONTHLY FLOWS

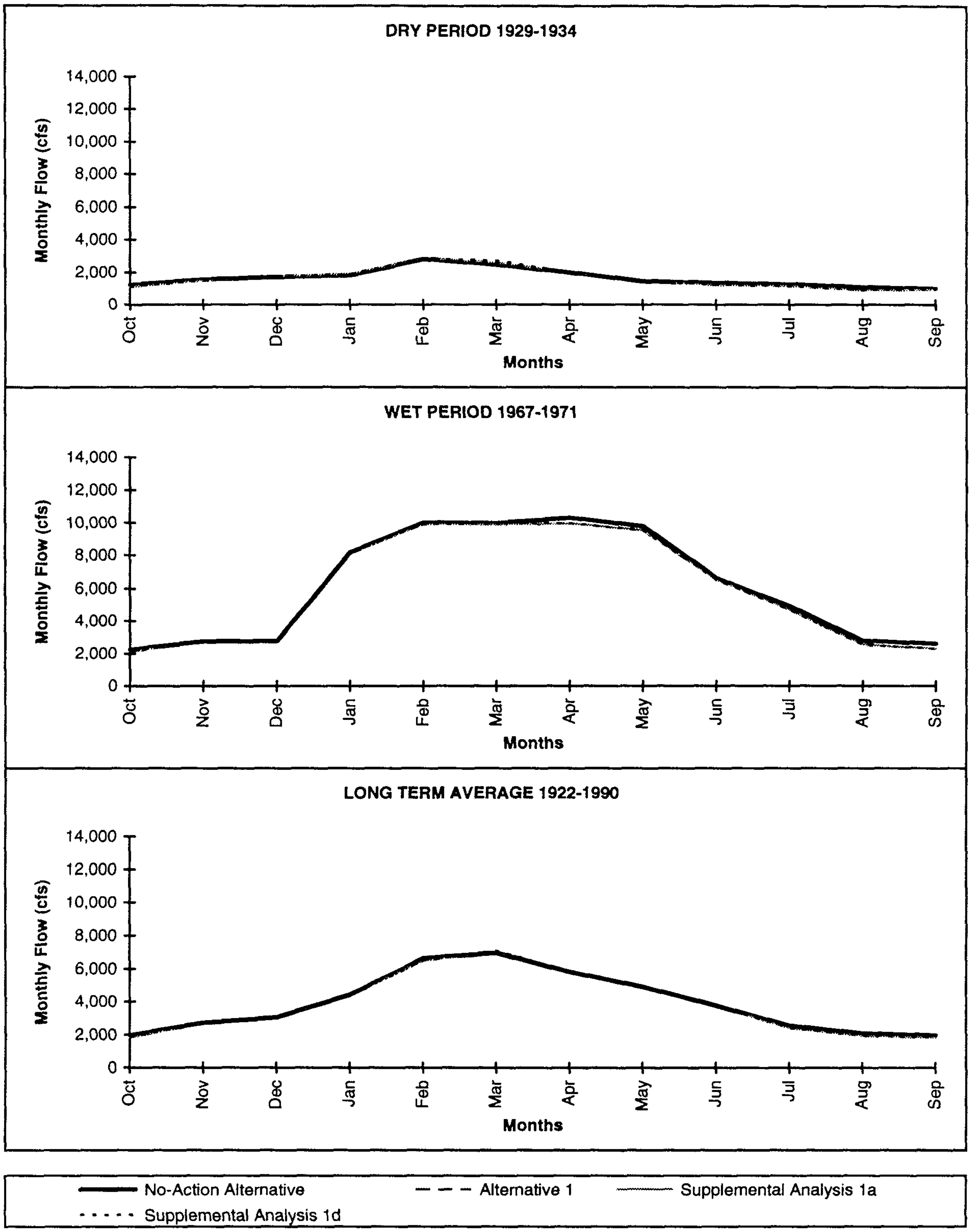


FIGURE III-34
SAN JOAQUIN RIVER AT VERNALIS
SIMULATED AVERAGE MONTHLY FLOWS

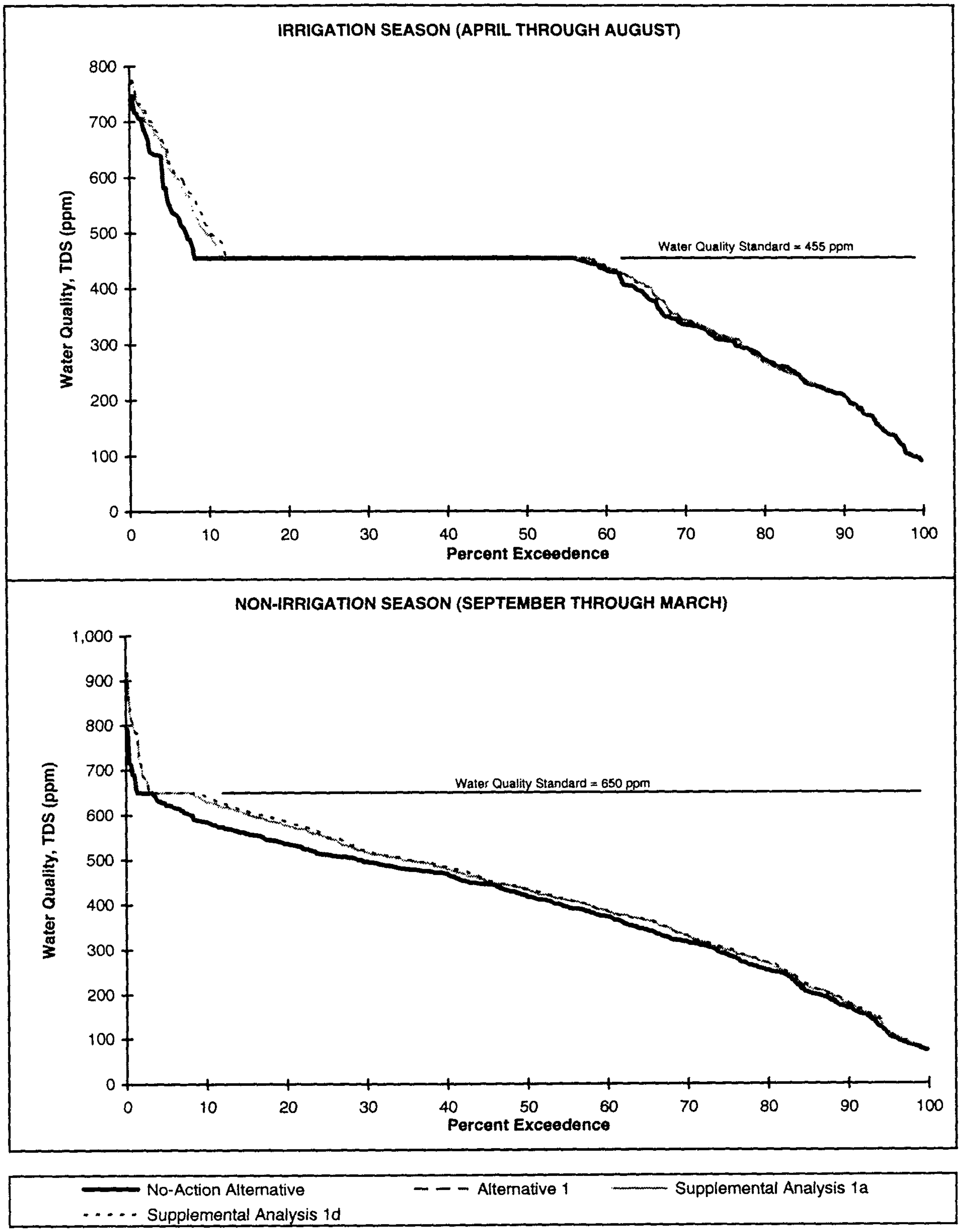


FIGURE III-35

SIMULATED MONTHLY WATER QUALITY AT VERNALIS

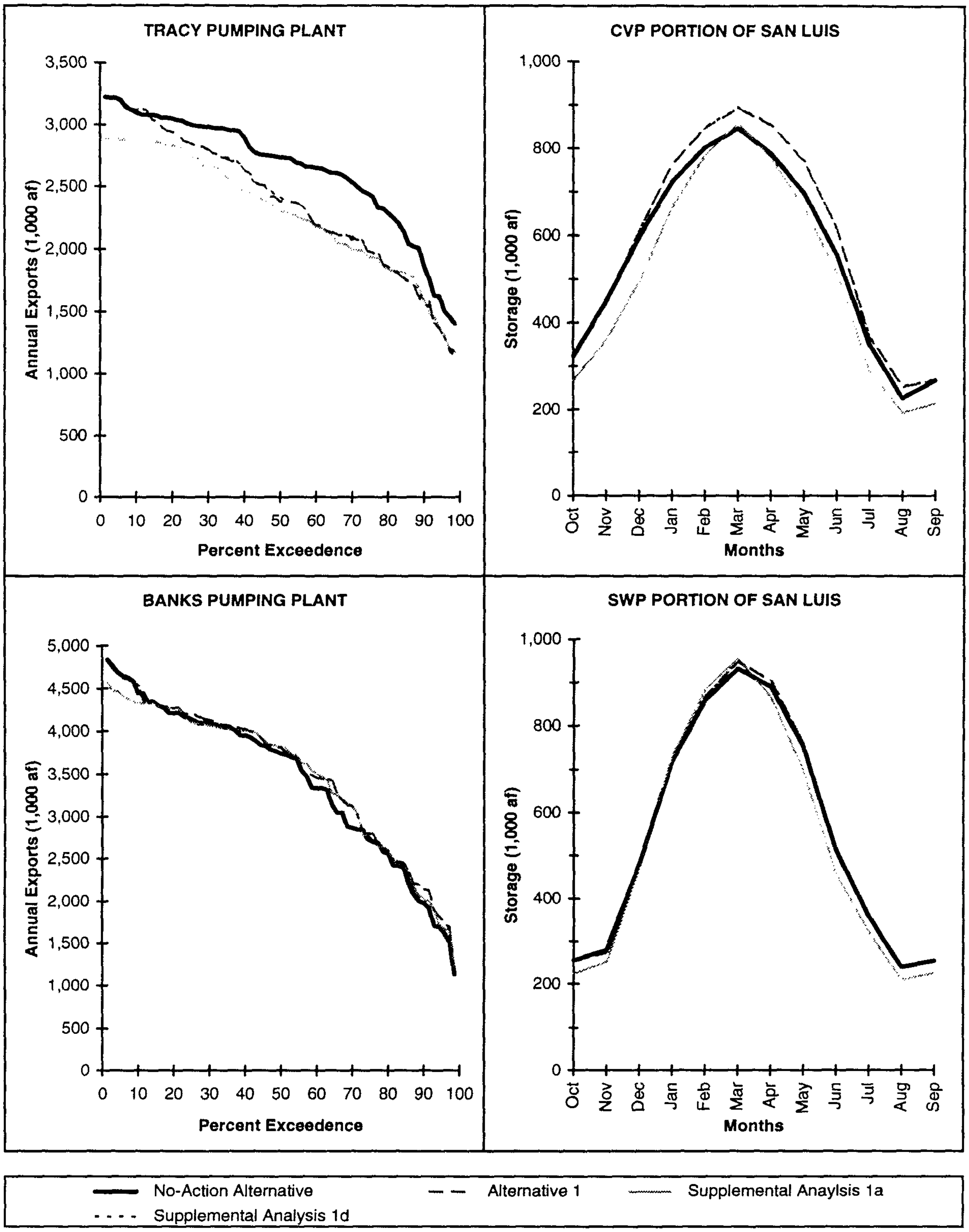


FIGURE III-36
SIMULATED ANNUAL EXPORTS AND SAN LUIS RESERVOIR AVERAGE END-OF-MONTH STORAGE 1922-1990

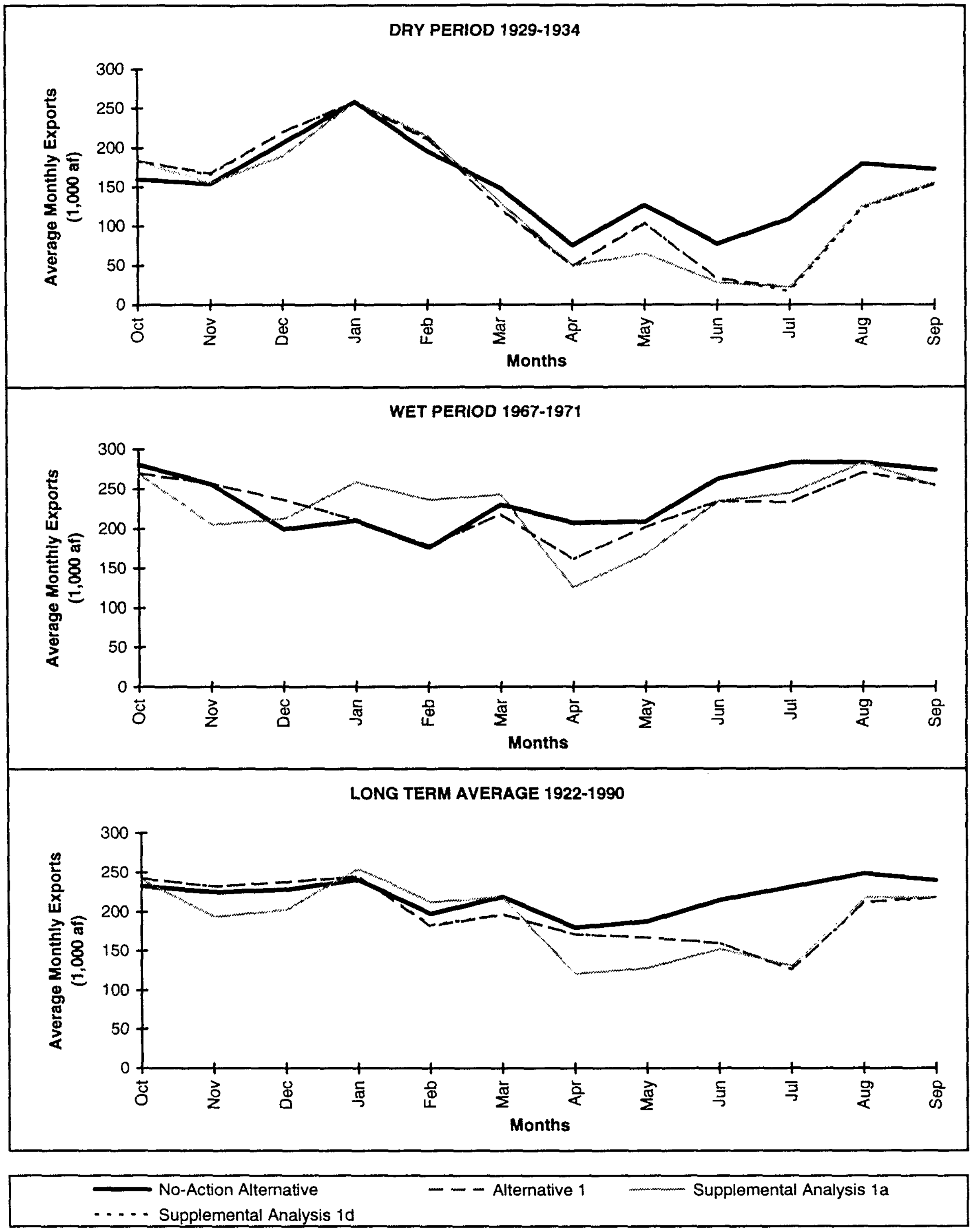


FIGURE III-37

TRACY PUMPING PLANT SIMULATED AVERAGE MONTHLY EXPORTS

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decrease in exports in November and December and in April and May as compared to Alternative 1. The figure also shows increased average monthly exports in roughly January through March, to make up for reduced pumping in previous months, in the wet and long-term average periods. In Supplemental Analysis 1a the average annual Delta outflow increases by about 80,000 acre-feet per year over the No-Action Alternative, and about 140,000 acre-feet per year over Alternative 1. The slight increase in Delta outflow in April, May, and June of the wet, above normal, and below normal years is a result of the April 15 through May 15 export restrictions and the increased number of X2 days at Chipps Island in May and June. Simulated average monthly Delta outflows in Supplemental Analysis 1a are shown in Figure III-38, as compared to Alternative 1 and the No-Action Alternative. The small increase in outflow resulting from the Delta (b)(2) actions is not discernable in the figure due to the large volume of Delta outflow.

West San Joaquin Division. The Delta (b)(2) actions limiting Tracy Pumping Plant exports April 15 through May 15, and in November and December reduce the CVP's flexibility to fill the CVP portion of San Luis Reservoir in the fall and supplement San Luis Reservoir releases in the spring. Figure III-36 shows simulated average monthly San Luis Reservoir CVP storage, as compared to Alternative 1 and the No-Action Alternative.

CVP Water Contract Deliveries

Alternative 1 includes the evaluation of the use of (b)(2) water to meet target goals on CVP controlled streams, firm Level 2 refuge supplies, and revised instream fishery releases on the Trinity River. In addition, Supplemental Analysis 1a includes the use of (b)(2) water in the attempt to meet fishery objectives in the Delta, as well as on CVP controlled streams. Because of the nature of the proposed Delta (b)(2) actions, the primary impact is to CVP water deliveries south of the Delta.

CVP Water Deliveries North of the Delta. As in Alternative 1, there would be no change in CVP deliveries to Sacramento River Water Rights Contractors as compared to the No-Action Alternative. Figure III-39 shows the comparison of Supplemental Analysis 1a and No-Action Alternative total annual deliveries to CVP agricultural contractors north of the Delta, including water rights and water service contractors. The change in annual deliveries to CVP M&I Water Service Contractors as compared to the No-Action Alternative is also shown in this figure. Comparisons of the frequency distributions for percent of full delivery to CVP agricultural and CVP M&I Water Service Contractors are presented in Figure III-40. The deliveries in Alternative 1 and Supplemental analysis 1a are very similar as compared to the No-Action Alternative.

CVP Water Deliveries Eastside Division. The deliveries to CVP contractors in the Eastside Division under Supplemental Analysis 1a would be the same as those described in Alternative 1, as shown by Figures III-39 and III-40.

CVP Water Deliveries South of the Delta. Deliveries to the San Joaquin River Exchange Contractors are the same as in the No-Action Alternative and Alternative 1. The comparison of Supplemental Analysis 1a and No-Action Alternative total annual deliveries to CVP agricultural contractors south of the Delta, including exchange and water service contracts, is shown in Figure III-41. A similar comparison for CVP M&I Water Service Contractors south of the Delta is also

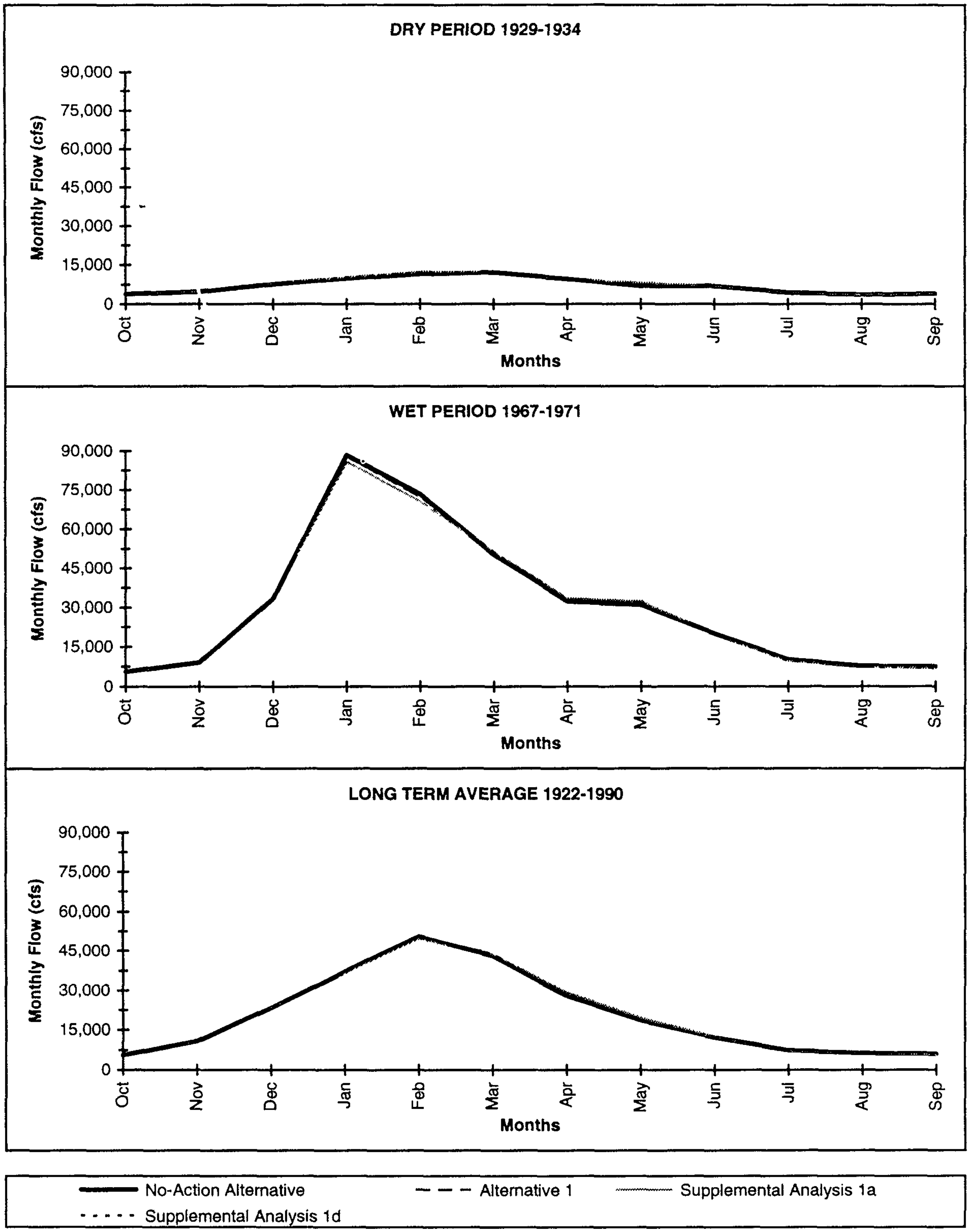
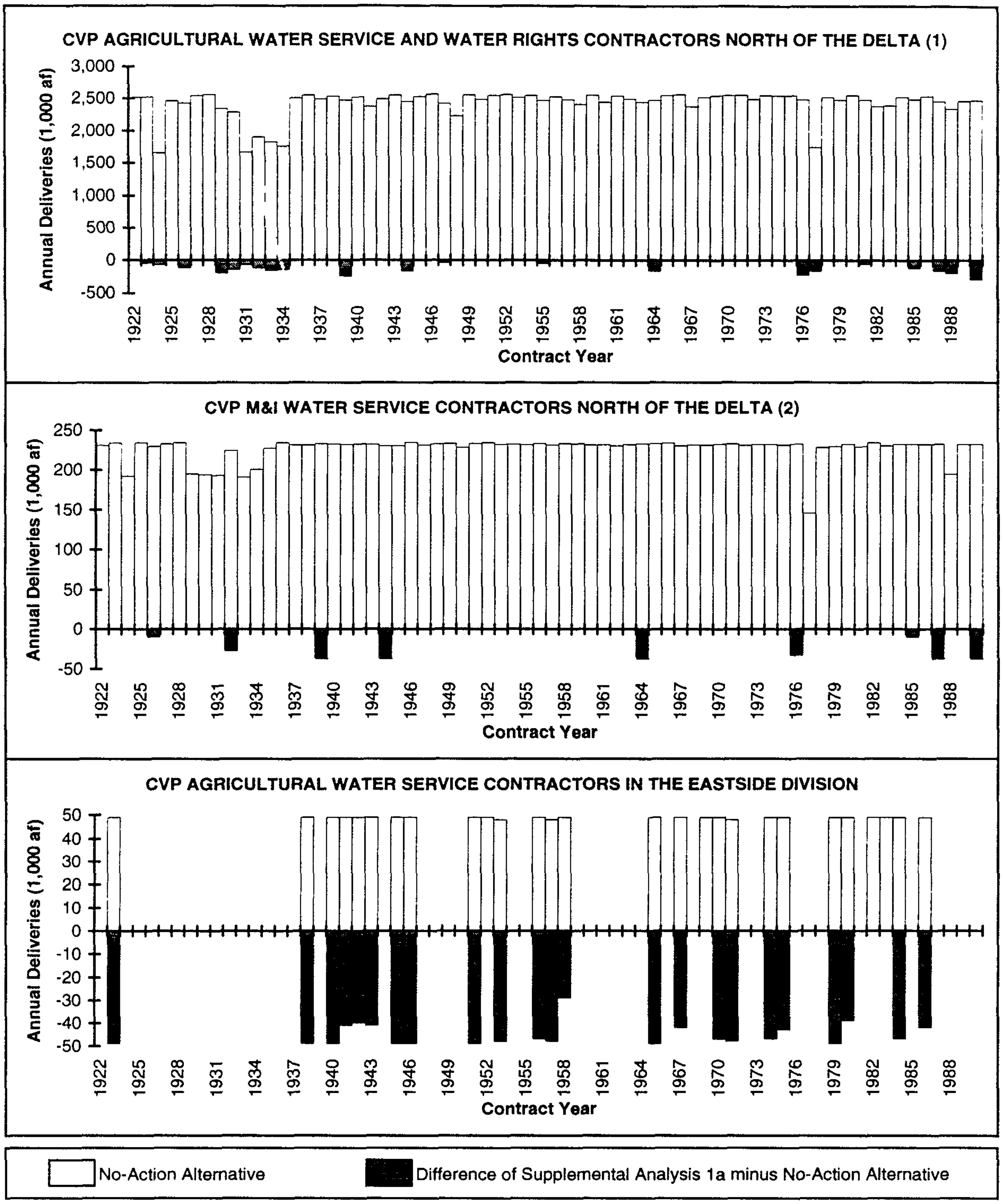


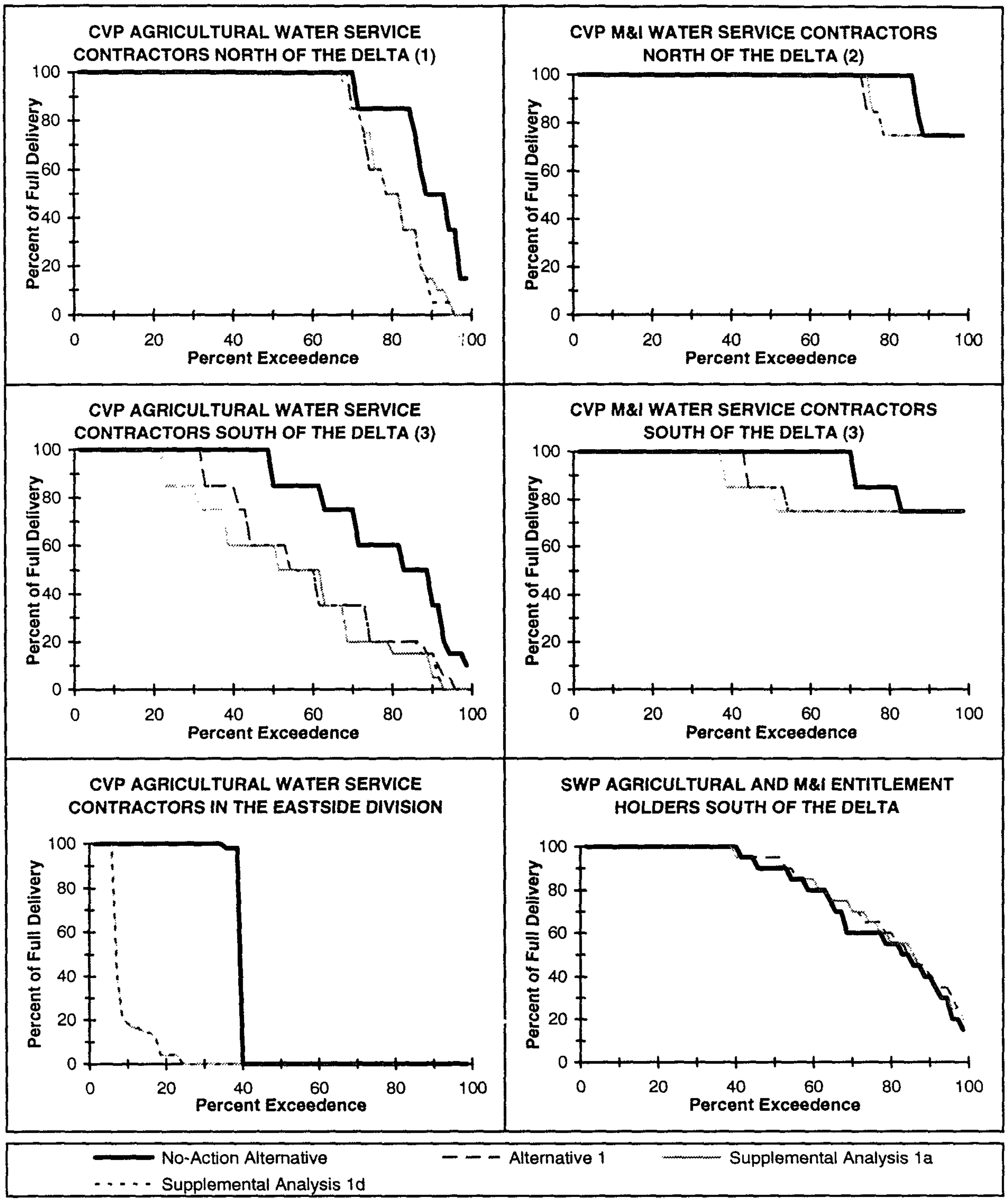
FIGURE III-38

DELTA OUTFLOW SIMULATED AVERAGE MONTHLY FLOWS



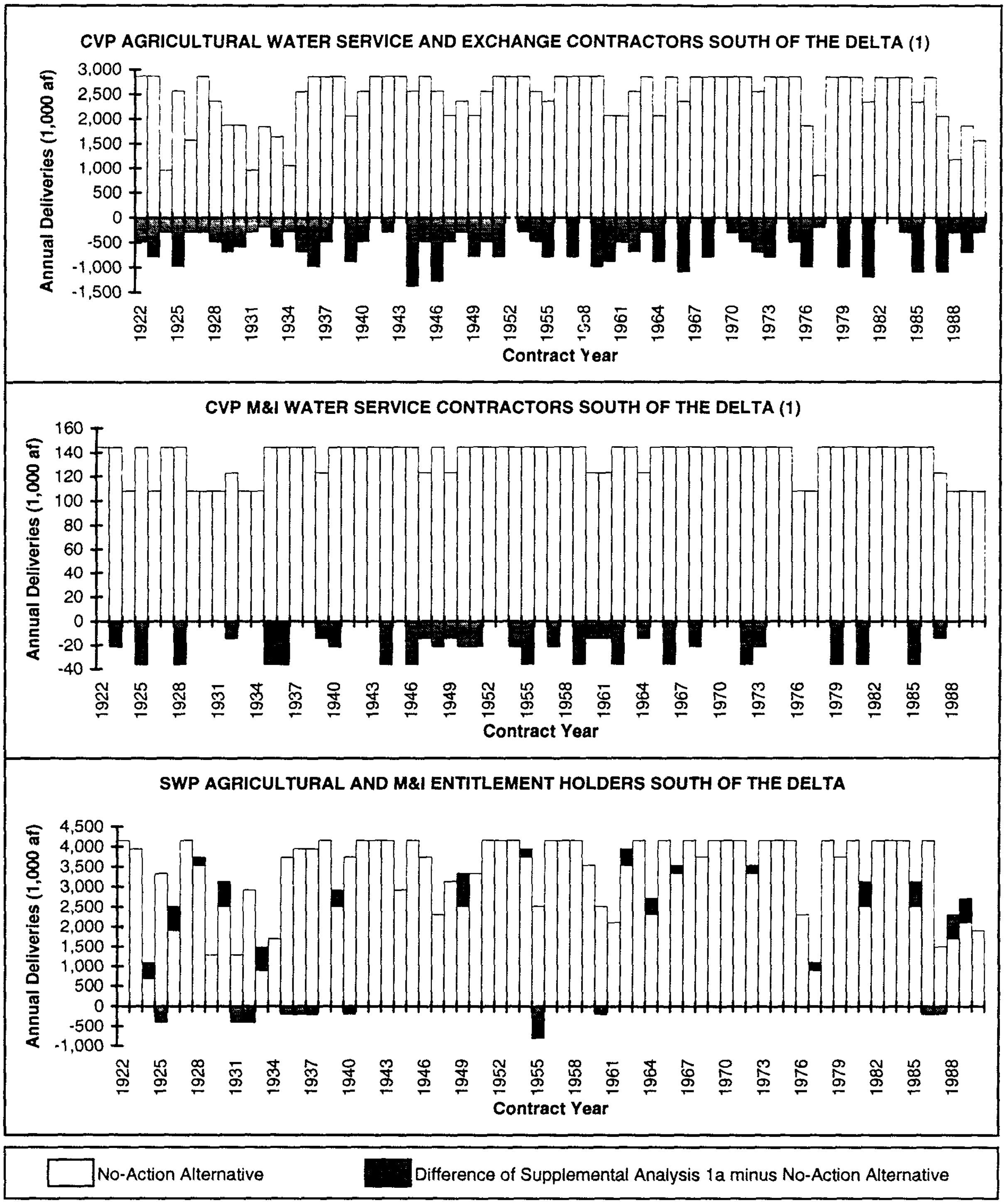
NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-39
SIMULATED SUPPLEMENTAL ANALYSIS 1a DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.
(3) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-40
SIMULATED FREQUENCY OF PERCENT OF FULL ANNUAL DELIVERIES 1922-1990



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-41
SIMULATED SUPPLEMENTAL ANALYSIS 1a DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990

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shown in this figure. The frequency distributions for CVP Agricultural and M&I Water Service Contractors percent of full delivery are presented in Figure III-40 as compared to the No- Action Alternative. The figure shows about a 5 to 10 percent reduction in the frequency of delivery as compared to Alternative 1, and about a 25 to 40 percent reduction in the frequency of deliveries as compared to the No-Action Alternative, except in the 10 percent lowest delivery years.

CVP Water Deliveries to Refuges. CVP deliveries to refuges in Supplemental Analysis 1a would be the same as in Alternative 1.

SUPPLEMENTAL ANALYSIS 1a IMPACTS ON SWP OPERATIONS AND DELIVERIES

Supplemental Analysis 1a assumes that the SWP would cooperate in attempting to meet the (b)(2) actions in the Delta. This cooperation would include reducing exports during the April 15 through May 15 pulse period and making releases to contribute to additional levels of Delta protection. Table III-7 shows a comparison of SWP deliveries for Supplemental Analysis 1a, Alternative 1, and the No-Action Alternative. In Alternative 1 the SWP deliveries increase by about 150,000 acre-feet per year on an average annual basis compared to the No-Action Alternative. In Supplemental Analysis 1a the increase over the No-Action Alternative is reduced to about 90,000 acre-feet per year due to the assumption that the SWP will cooperate in helping to implement the (b)(2) actions in the Delta. A discussion of the Supplemental Analysis 1a impacts to SWP operations is provided below.

TABLE III-7
COMPARISON OF SWP DELIVERIES IN SUPPLEMENTAL ANALYSIS 1a, ALTERNATIVE 1, AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual SWP Deliveries (1,000 acre-feet)			Alternative 1a and No-Action Alternative:
		No-Action Alternative	Alternative 1	Supplemental Analysis 1a	Average Annual Change in SWP Deliveries (1,000 acre-feet)
1922 - 1990	Simulation Period	3,330	3,430	3,390	+60
1928 - 1934	Dry Period	2,050	2,200	2,140	+90
1967 - 1971	Wet Period	4,140	4,100	4,140	0

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

SWP Operations

SWP operations in Supplemental Analysis 1a are affected by the need to make higher Lake Oroville releases for the increased number of X2 days at Chipps Island, and by the limitation on Banks Pumping Plant exports April 15 through May 15. The impacts to SWP operations are described below.

Lake Oroville and Feather River Operations. The implementation of Delta (b)(2) actions in Supplemental Analysis 1a would have minimal impact on SWP upstream Lake Oroville operations, as shown in Figure III-28. Similarly, these actions would result in minimal changes to flows in the Feather River flows at Nicolaus, as shown in Figure III-42 as compared to Alternative 1 and the No-Action Alternative.

Delta Operations. The shift in average monthly Banks Pumping Plant exports is shown in Figure III-43 for the dry, wet, and 69-year simulation period. The figure show the Supplemental Analysis 1a export reductions in April and May, as well as a slight increase in fall and winter exports to make up for the April and May restrictions. The increase in Banks Pumping Plant exports is only slightly higher in November and December because the pumping plant is usually at capacity already in these months. Figure III-36 shows a comparison of the frequency distributions for annual Banks Pumping Plant exports for the simulation period 1922 through 1990.

San Luis Reservoir Operations. As a result of the limitations to Banks Pumping Plant April 15 through May 15, there would be some additional drawdown to the SWP portion of San Luis Reservoir in the spring, especially during wet years when the 1,500 cfs maximum total pumping limit has the greatest impact on exports. Figure III-36 shows a comparison of simulated average monthly SWP storage in San Luis Reservoir.

SWP Entitlement Water Deliveries

In Supplemental Analysis 1a, SWP deliveries are greater than in the No-Action Alternative, but reduced as compared to Alternative 1, due to the additional Delta (b)(2) actions. Figure III-41 shows simulated annual SWP agricultural and M&I deliveries as compared to the No-Action Alternative. The frequency distributions for the simulated percent of full contract delivery to SWP Agricultural and M&I entitlement holders south of the Delta in the No-Action Alternative, Alternative 1, and Supplemental Analysis 1a are presented in Figure III-40. Full contract delivery occurs in 40 percent of the years in all three simulations. The delivery increases in Alternative 1 and Supplemental Analysis 1a are similar, as compared to the No-Action Alternative. These increases in entitlement deliveries are a result of increased fall and winter SWP pumping through Banks Pumping Plant.

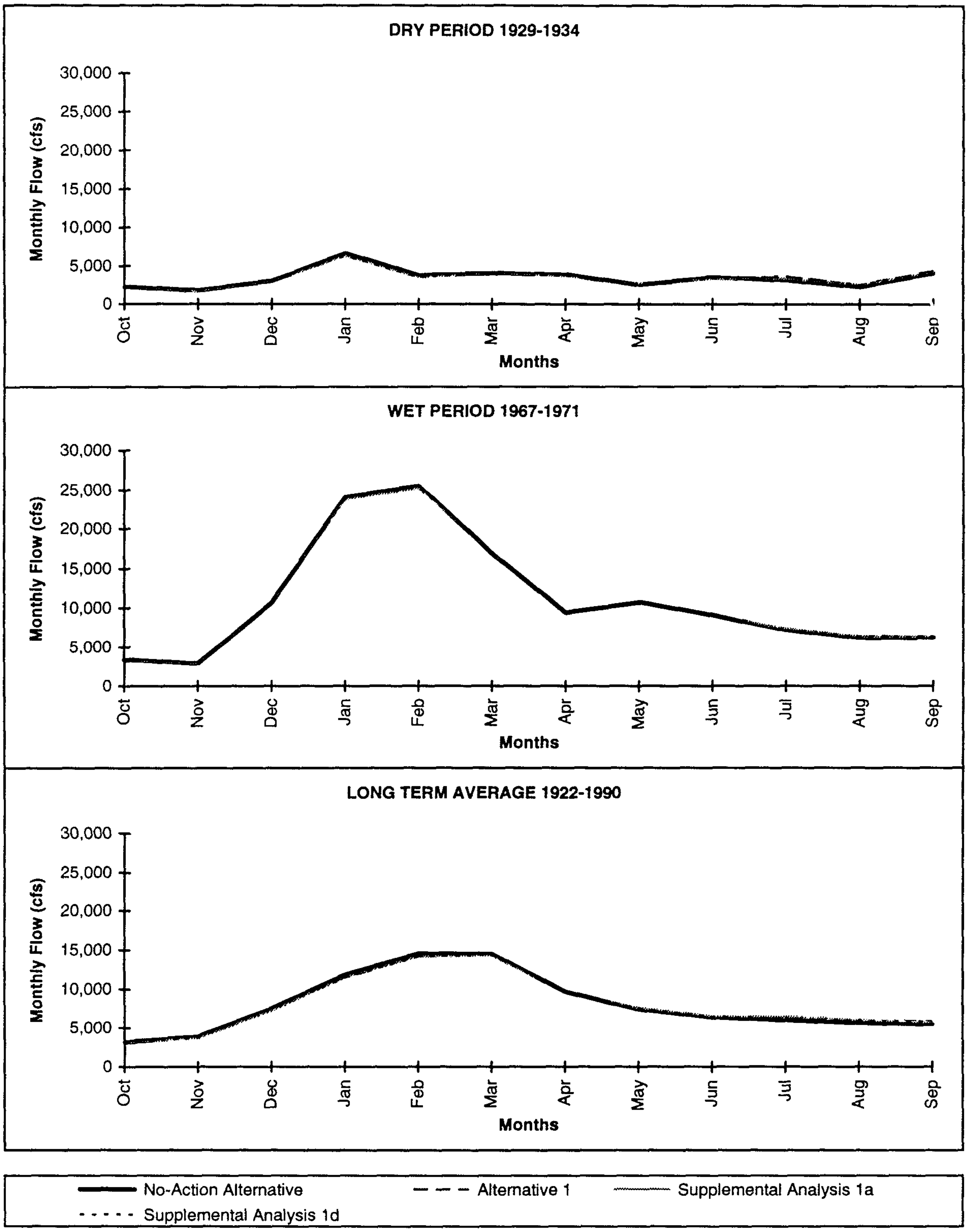


FIGURE III-42

FEATHER RIVER AT NICOLAUS SIMULATED AVERAGE MONTHLY FLOWS

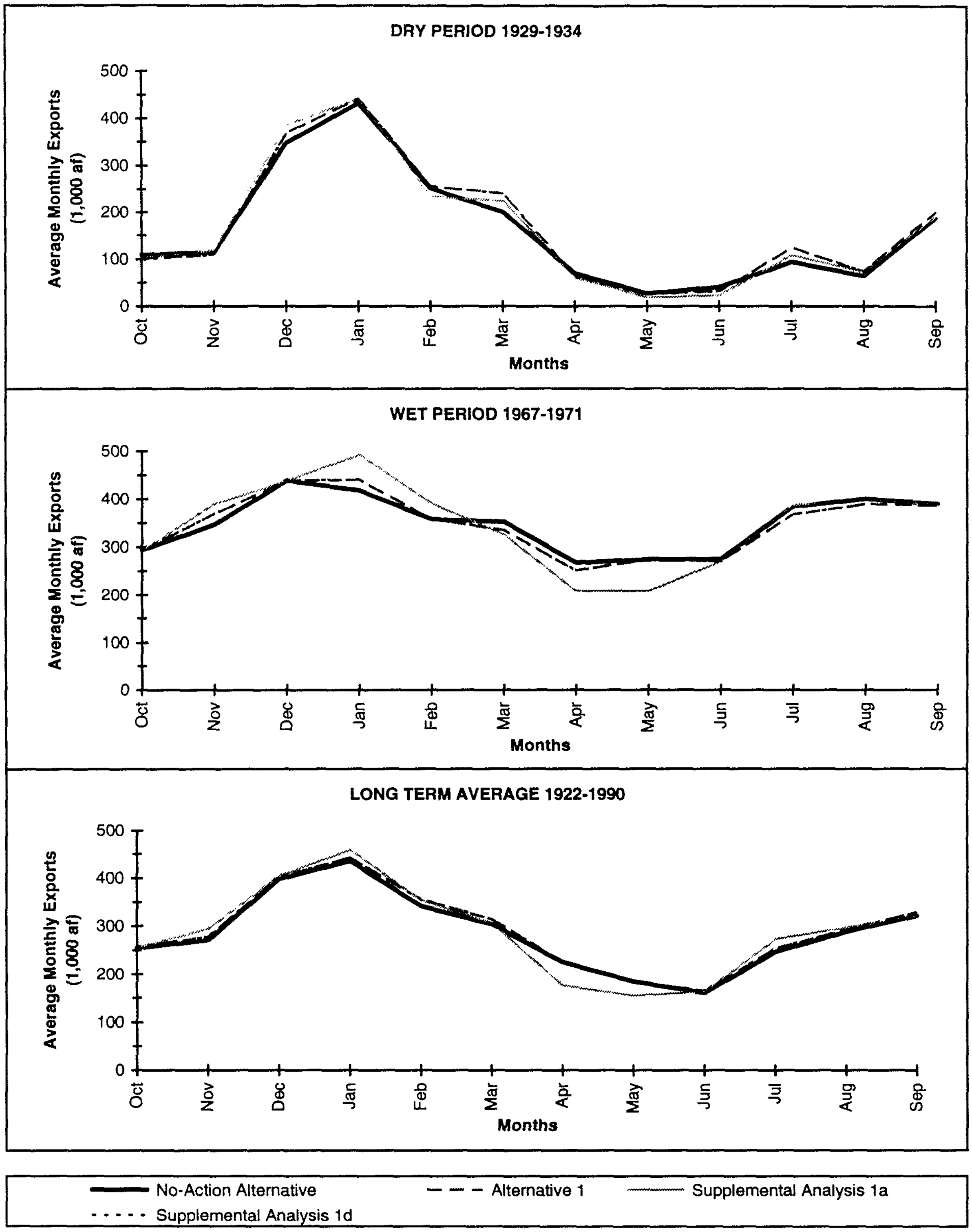


FIGURE III-43

BANKS PUMPING PLANT SIMULATED AVERAGE MONTHLY EXPORTS

SUPPLEMENTAL ANALYSIS 1d

DESCRIPTION OF SUPPLEMENTAL ANALYSIS

In Supplemental Analysis 1d, the CVP and SWP would be operated in accordance with all criteria described in the No-Action Alternative and Alternative 1, with the exception that shortages would not be applied to firm Level 2 refuge water supply deliveries. In the No-Action Alternative and Alternative 1 simulations, refuge water supplies are subject to deficiencies in accordance with the Shasta Criteria. As discussed in Chapter II, the Shasta Criteria apply when forecasted inflows to Shasta Lake fall below the defined thresholds, and water deliveries may be reduced up to 25 percent in these critical years. In the No-Action Alternative and Alternative 1, the following six years are considered critical based on the Shasta Criteria: 1924, 1931, 1932, 1933, 1934, and 1977. Unlike the No-Action Alternative and Alternative 1 simulations, Supplemental Analysis 1d does not include shortages to refuge water supplies in those six years. The Supplemental Analysis 1d delivery of Level 2 water supplies in the remaining years would be identical to Alternative 1.

In each of the six critical years, approximately 130,000 acre-feet per year of additional water would be delivered to the refuges to provide full delivery of Level 2 water supplies. In these critical years, the deliveries to CVP M&I water service contractors have already been reduced to the minimum delivery of 75 percent of full water service contracts. Therefore, the increased delivery of water to refuges would result in reduced water deliveries to agricultural water service contractors, as compared to Alternative 1.

SUPPLEMENTAL ANALYSIS 1d IMPACTS ON CVP OPERATIONS AND DELIVERIES

Supplemental Analysis 1d CVP reservoir and export operations are similar to Alternative 1, because the difference in refuge deliveries only applies to six years in the 1922 through 1990 simulation period. Agricultural water service contract deliveries would decrease in some of the critical years as a result of the increased refuge deliveries. A comparison of CVP deliveries in the Supplemental Analysis 1d, Alternative 1, and No-Action Alternative simulations is provided in Table III-8.

TABLE III-8
COMPARISON OF CVP DELIVERIES IN SUPPLEMENTAL ANALYSIS 1d, ALTERNATIVE 1 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet)			Analysis 1d and No-Action Alternative:
		No-Action Alternative	Alternative 1	Supplemental Analysis 1d	Average Annual Change in CVP Deliveries (1,000 acre-feet)
1922 - 1990	Simulation Period	5,770	5,300	5,290	-480
1928 - 1934	Dry Period	4,560	4,050	4,000	-560
1967 - 1971	Wet Period	6,310	6,020	6,020	-290

Notes:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.

CVP Operations

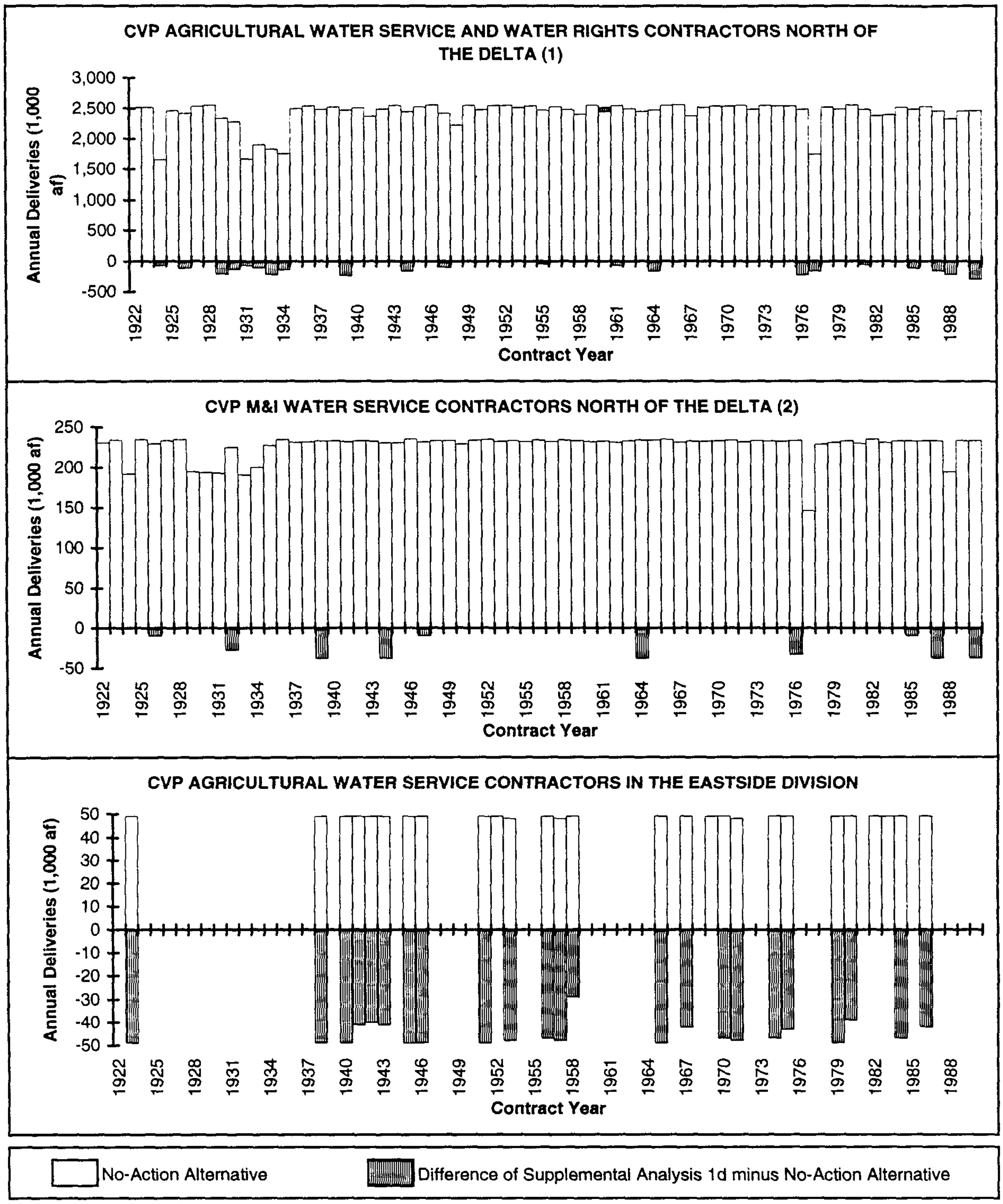
Under Supplemental Analysis 1d, reservoir operations and river flow regimes in Trinity, Shasta, Sacramento, Delta, Eastside, and West San Joaquin Divisions would be similar to those described in Alternative 1. Water quality conditions on the San Joaquin River at Vernalis would also be similar to those described in Alternative 1. Figures III-28 through III-38 show the results of Supplemental Analysis 1d CVP operations as compared to Supplemental Analysis 1a, Alternative 1, and the No-Action Alternative.

CVP Water Contract Deliveries

Frequency distributions of the simulated percent of full contract delivery to CVP contractors in the No-Action Alternative, Alternative 1, and Supplemental Analyses 1a and 1d simulations are presented in Figure III-40. Annual deliveries to CVP contractors under Supplemental Analysis 1d, as compared to the No-Action Alternative, are shown in Figures III-44 and III-45.

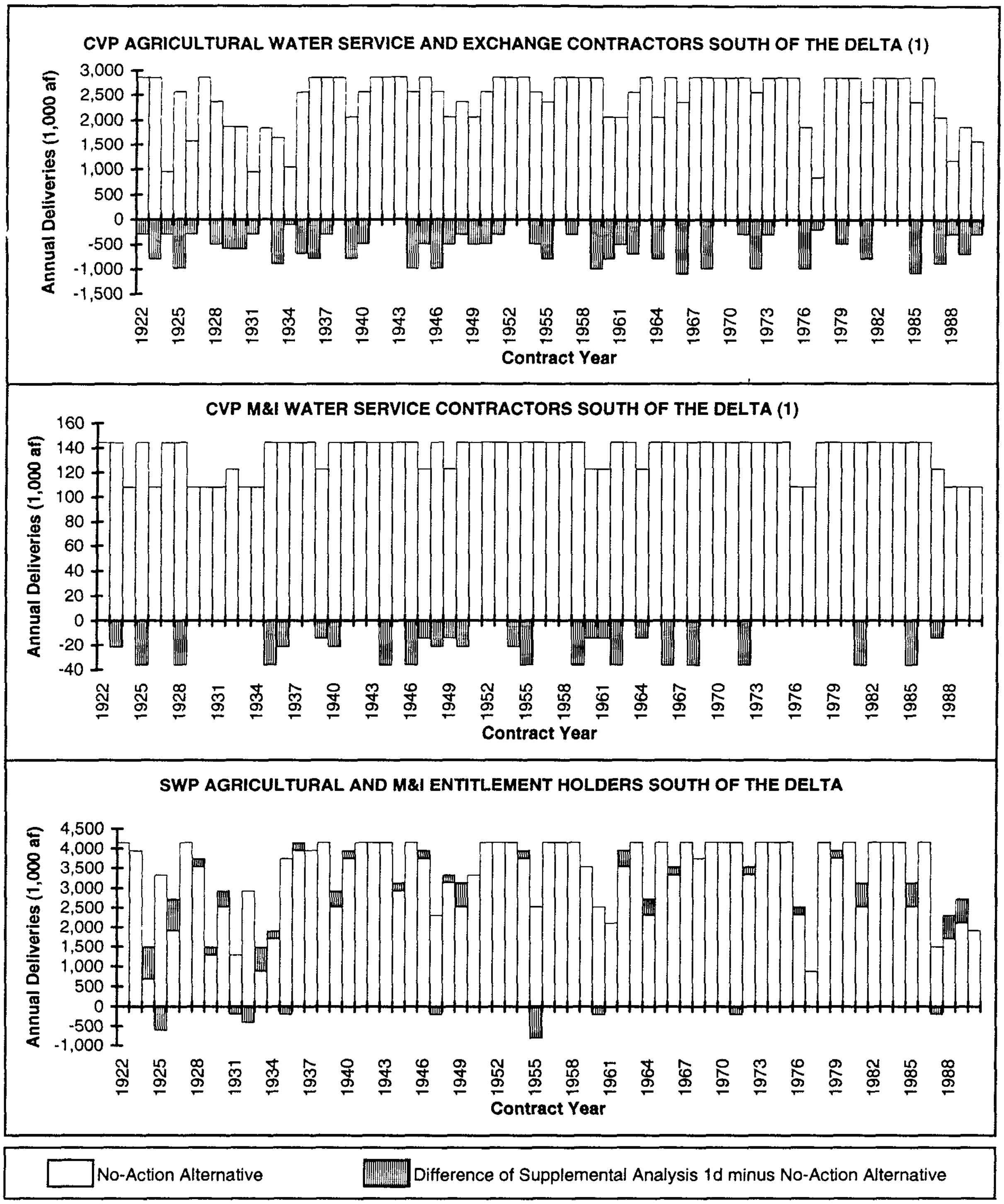
CVP Water Deliveries North of the Delta. CVP water deliveries to Sacramento River Water Rights Contractors do not change in Supplemental Analysis 1d. Deliveries to water service contractors in Supplemental Analysis 1d are similar to those in Alternative 1, except in critical dry years when deliveries are further reduced to provide full refuge water supplies.

CVP Water Deliveries Eastside Division. The deliveries to CVP agricultural water service contractors on the Stanislaus River in Alternative 1d would be similar to those described in Alternative 1.



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-44
SIMULATED SUPPLEMENTAL ANALYSIS 1d DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-45
SIMULATED SUPPLEMENTAL ANALYSIS 1d DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990

CVP Water Deliveries South of the Delta. CVP deliveries to San Joaquin River Exchange Contractors do not change in Supplemental Analysis 1d because their delivery deficiencies are based on the Shasta Criteria. Deliveries to water service contractors in Supplemental Analysis 1d are similar to those in Alternative 1, except in critical dry years.

CVP Water Deliveries To Refuges. Supplemental Analysis 1d includes delivery of firm Level 2 wat:r supplies to refuges in all years without shortage.

SUPPLEMENTAL ANALYSIS 1d IMPACTS ON SWP OPERATIONS AND DELIVERIES

Supplemental Analysis 1d SWP Lake Oroville and Banks Pumping Plant operations would be very similar to operations in the Alternative 1, because the changes in refuge deliveries in critical years would have no impact on the operation of the SWP. A summary of impacts to SWP deliveries for Supplemental Analysis 1d, Alternative 1, and the No-Action Alternative is provided in Table III-9.

SWP Operations

As explained above, Supplemental Analysis 1d reservoir operations for Lake Oroville and the SWP portion of San Luis Reservoir are similar to those in Alternative 1. Releases from Lake Oroville on the Feather River below Gridley and Nicolaus are similar to those in the Alternative 1. Exports through Banks are similar in those of Alternative 1.

TABLE III-9
COMPARISON OF SWP DELIVERIES IN SUPPLEMENTAL ANALYSIS 1d, ALTERNATIVE 1 AND NO-ACTION ALTERNATIVE SIMULATIONS

		Simulated Average Annual SWP Deliveries (1,000 af)			Analysis 1d and No-Action Alternative:
Contract Years	Type of Period	No-Action Alternative	Alternativ e 1	Supplemental Analysis 1d	Average Annual Change in SWP Deliveries (1,000 af)
1922 - 1990	Simulation Period	3,330	3,430	3,430	+100
1928 - 1934	Dry Period	2,050	2,200	2,200	+150
1967 - 1971	Wet Period	4,140	4,100	4,100	-40

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

SWP Entitlement Water Deliveries

Supplemental Analysis 1d deliveries to SWP agricultural and M&I entitlement holders south of the Delta would be similar to those in Alternative 1. Figure III-40 shows a comparison of frequency distributions for SWP deliveries in Supplemental Analyses 1d and 1a, Alternative 1, and the No-Action Alternative. Figure III-45 shows the difference between SWP deliveries in Supplemental Analysis 1d and the No-Action Alternative.

ALTERNATIVE 2

DESCRIPTION OF ALTERNATIVE

Alternative 2 includes the CVPIA provisions in Alternative 1, plus the acquisition of surface water from willing sellers toward meeting the delivery of Level 4 water supplies to refuges and meeting target flows for chinook salmon and steelhead trout in Central Valley streams. The Re-operation and (b)(2) Water Management components of Alternative 2 are similar to these components in Alternative 1. Alternative 2 also includes the implementation of the same habitat restoration actions included in Alternative 1.

Under Alternative 2, water would be acquired to provide delivery of Level 4 water supply requirements to wildlife refuges. It is assumed that this water would be acquired from reliable sources within the same geographic region as the refuges.

In addition, Alternative 2 includes the acquisition of water on the Stanislaus, Tuolumne, and Merced rivers, and the release of this water to help meet salmon and steelhead target flows on these streams, primarily in the April through June period, and to provide increased Delta outflow. Because this water would be acquired for both instream flows and Delta outflow, it could not be pumped by export facilities in the Delta. It is recognized that this assumption, in practice, would require a SWRCB review process to establish instream flow and Delta outflow as beneficial uses of acquired water. The release of acquired water to increase flows on the Stanislaus, Tuolumne, and Merced rivers would result in increased flows in the San Joaquin River at Vernalis. Increased flows during April and May would decrease the number of occurrences when the Bay-Delta Plan Accord pulse flow requirements on the San Joaquin River at Vernalis would not be met.

Similar to Alternative 1, the CVP would be operated under Alternative 2 in an attempt to increase end-of-month storage levels in September in Shasta and Folsom lakes in order to provide increased river releases during the fall in the Sacramento and American rivers. Increased reservoir releases would also be made from Whiskeytown Lake to increase Clear Creek minimum flows year round, and from New Melones Reservoir to provide higher flows on the Stanislaus River to attempt to meet target flows. Increased Clair Engle Lake releases, to meet increased Trinity River instream fishery flow releases in this alternative, result in a decrease in spring and early summer imported flows to the Sacramento River.

Also similar to Alternative 1, Alternative 2 includes implementation of the habitat restoration actions, as described in Attachment F to the Draft PEIS.

WATER ACQUISITION IN ALTERNATIVE 2

Water would be acquired in Alternative 2 for two purposes: Level 4 refuge water supplies, and instream flows on the Stanislaus, Tuolumne, and Merced rivers. A description of the assumptions for the acquisition of water in Alternative 2 is provided below.

Water Acquisition for Level 4 Refuge Water Supplies

Level 4 refuge water supplies are defined in the 1989 and 1992 Refuge Water Supply Studies as the amount of water necessary to support full development of the refuges based upon management goals developed in the 1980s. The Level 4 refuge water supply requirements are presented in Table III-10.

In Alternative 2, water would be acquired from willing sellers to provide the difference between Level 2 and Level 4 refuge water supply requirements. It is assumed that surface water for refuges north of the Delta would be acquired from the Sacramento River Water Rights Contractors. It is assumed that surface water for refuges south of the Delta, with the exceptions of Kern NWR, Pixley NWR, Merced NWR, and the East Gallo Unit, would be acquired from San Joaquin River Exchange Contractors. Surface water for Kern and Pixley NWRs would be acquired from local supplies or from SWP contractors in the Tulare Basin. Water would be acquired for the Merced NWR and the East Gallo Unit from water rights holders on the Merced River. A summary of assumed acquisition quantities is presented in Table III-11.

As a condition of the acquisition of water from willing sellers, it is assumed that shortage criteria applied to the source of the water would also apply to the acquired quantities. Because the release pattern of acquired water would be shifted within an annual period, and the quantity of water would be subject to the same shortage criteria as the seller, end-of-year reservoir storage levels would be similar to those described in the Alternative 1 simulation.

It is also assumed that as a condition of long-term water acquisition, willing sellers could not replace the sold surface water supplies with additional groundwater pumping.

Water Acquisition for Instream Flows and Delta Outflow

In Alternative 2, surface water would be acquired from willing sellers on the Stanislaus, Tuolumne, and Merced rivers, and would be released in a manner to help meet target flows on these streams and increase Delta outflow. For the purposes of this analysis, it is assumed that the maximum quantity of water to be acquired from each source would be the same in all years. Depending on hydrologic conditions, the actual amount of water that would be acquired in any year could be less than the maximum quantity.

TABLE III-10
LEVEL 4 REFUGE WATER SUPPLIES

Refuge	Level 4 Water Supplies (1,000 acre-feet)			Notes
	At Boundary	Conveyance Loss	To Be Diverted	
SACRAMENTO VALLEY REFUGES				
Sacramento NWR	50.0	16.7	66.7	Source: Conveyance loss on CVP and Level 4 water is 25 percent.
Delvan NWR	30.0	10.0	40.0	Source: Conveyance loss on CVP and Level 4 water is 25 percent.
Colusa NWR	25.0	8.3	33.3	Source: Conveyance loss on CVP and Level 4 water is 25 percent.
Sutter NWR	30.0	3.3	33.3	Source: CVP provides Level 2 through exchanges. Conveyance loss on CVP and Level 4 water is 10 percent..
Grey Lodge NWR	44.0	7.0	51.0	Source: BWGID provides Level 1. CVP through exchanges provides remaining Level 2. Conveyance loss on CVP and Level 4 water is 17 percent.
TOTAL FOR SACRAMENTO VALLEY REFUGES	**179.0**	**45.3**	**224.3**	
SAN JOAQUIN VALLEY REFUGES				
San Luis NWR	19.0	6.3	25.3	Source: Conveyance loss on CVP water is 15 percent.
Kesterson NWR	10.0	1.1	11.1	Source: Conveyance loss on 6,500 af of CVP water is 15 percent.
Volta WMA	16.0	0.0	16.0	Source: No loss due to delivery through Volta Wasteway, including Level 4 water.
Los Banos WMA	25.5	5.1	30.6	Source: Conveyance loss on 19.3 af of CVP and Level 4 water is 21 percent. No loss for 6,200 acre-feet.
San Joaquin Basin Action Plan Lands				
Freitas	5.3	1.8	7.1	Source: Conveyance loss on CVP water is 25 percent.
East Gallo	13.3	4.4	17.7	Source: Merced River users. Conveyance loss on water is 25 percent.
West Gallo	10.8	3.6	14.4	Source: Conveyance loss on CVP water is 25 percent.
Salt Slough	10.0	1.8	11.8	Source: Conveyance loss on CVP and Level 4 water is 15 percent.
China Island	10.5	1.8	12.3	Source: Conveyance loss on CVP and Level 4 water is 15 percent.
Grasslands RCD	180.0	31.8	211.8	Source: Conveyance loss on CVP and Level 4 water is 15 percent.
Mendota WMA	29.6	0.0	29.6	Source: No losses due to delivery at Mendota Pool.
Merced NWR	16.0	5.3	21.3	Source: Merced Irrigation District in accordance wit a FERC agreement. Losses for Levels 2 and 4 water are 25 percent.
Kern NWR	25.0	3.7	28.7	Source: Conveyance loss on CVP and Level 4 water is 13 percent.
Pixley NWR	6.0	0.8	6.8	Source: Conveyance loss of CVP and Level 4 water is 15 percent.
TOTAL FOR SAN JOAQUIN VALLEY REFUGES	**377.0**	**67.5**	**444.5**	
TOTAL FOR ALL REFUGES	**556.0**	**112.8**	**668.8**	

TABLE III-11
SURFACE WATER ACQUISITION FOR LEVEL 4 REFUGE WATER SUPPLIES

Refuge(s)	Annual Acquisition Amount (1,000 acre-feet)
Refuges North of the Delta	34.5
Refuges South of the Delta	130.8

The acquisition targets and long-term average acquisition quantities for water purchased from willing sellers for instream flows on the Stanislaus, Tuolumne, and Merced rivers is shown in Table III-12. The acquisition of up to 50,000 acre-feet per year from sources on the Merced River would occur in addition to the acquisition of 19,000 acre-feet per year for Level 4 refuge water supplies to the Merced NWR and East Gallo Unit. Therefore, the total amount of water acquired from willing sellers on the Merced River would be up to 69,000 acre-feet per year.

It is assumed that water would be acquired from water rights holders on the Stanislaus, Tuolumne, and Merced rivers that possess diversion and storage rights on these rivers. The acquired water would be stored during the period of a contract year (March - February), and released in a manner to increase flows toward meeting the instream flow targets on these rivers and to increase Delta outflow. In effect, the acquisition of water would involve a shift in the release pattern from storage reservoirs, combined with a reduction in diversions by the willing sellers. It is assumed that acquired water would be stored and released from New Melones Reservoir on the Stanislaus River, New Don Pedro Reservoir on the Tuolumne River, and Lake McClure on the Merced River.

TABLE III-12
SUMMARY OF LONG-TERM AVERAGE ANNUAL WATER ACQUISITION QUANTITIES FOR INSTREAM FLOWS (IN 1,000 ACRE-FEET)

	Alternative 2		Alternatives 3 and 4	
Location	Target	Long-Term Average	Target	Long-Term Average
Merced River	50	50	200	194
Tuolumne River	60	60	200	197
Stanislaus River	60	49	200	194
Calaveras River	–	–	30	27
Mokelumne River	–	–	70	62
Yuba River	–	–	100	87

In Alternative 2, the acquisition of water from willing sellers would be associated with reduced agricultural water use, and would therefore result in reduced return flows to downstream portions of the rivers. This could result in reductions of flows required to meet water rights obligations to downstream areas (base flows). To avoid unintended impacts to downstream water users, base flow conditions would be maintained in portions of rivers that would be affected by the use of acquired water. To accomplish this, a portion of the acquired water would be released from the reservoirs to maintain base flow conditions similar to those conditions in the No-Action Alternative. In the simulation of this alternative, this ensures that downstream users would have access to flows consistent with their water rights.

The accounting of acquired surface water for instream and Delta outflow purposes is computed on a contract year basis. The maximum quantity of water to be acquired in each year would be determined at the beginning of March. The quantity would be based on the fishery flow targets that would be applicable from March through the following February. These flow targets would be based on the water year type, as determined on March 1. The quantity of water that would be acquired on each river would be limited to either the maximum acquisition quantity assumed in the alternative, or the maximum quantity needed to meet the target instream flows for the particular year, whichever is less. It is therefore assumed that acquired water would not be carried over to subsequent years. Releases of acquired water from reservoir storage would begin at the start of the contract year in March, and continue through the end of the contract year in the following February. Irrigation diversions from March through October would be reduced to provide the water to be released over the contract year.

Rescheduling releases of acquired water could affect storage conditions in reservoirs during the irrigation season, as compared to the No-Action Alternative. If the acquired water is released toward meeting target flows in the spring, releases in the early part of the irrigation season would generally be greater than in the No-Action Alternative, and storage conditions through the summer months would be lower than in the No-Action Alternative. As a result, some of the late summer releases that would be made to evacuate flood control storage in the No-Action Alternative would not be as large, or would not occur. Because the flows during the late summer months could be reduced due to this condition, water quality conditions in the San Joaquin River at Vernalis could become degraded to the extent that the water quality standards would be exceeded, as compared to the No-Action Alternative. Therefore, in such cases, portions of the acquired water would be released in a manner to maintain the water quality conditions equal to the No-Action Alternative on a percent exceedence basis.

Changes in storage in New Melones Reservoir are described in the discussion of the impacts of Alternative 2 on CVP operations. This information is provided because New Melones is a CVP facility and is simulated in the Draft PEIS analysis for all authorized purposes. On non-CVP facilities, such as New Don Pedro Reservoir and Lake McClure, simulation for the Draft PEIS analysis only addresses releases for diversions and instream flow requirements, and does not consider potential changes to operations to accommodate power generation, recreation, or coordinated operations with upstream facilities. Therefore, only releases below these facilities are provided in this analysis.

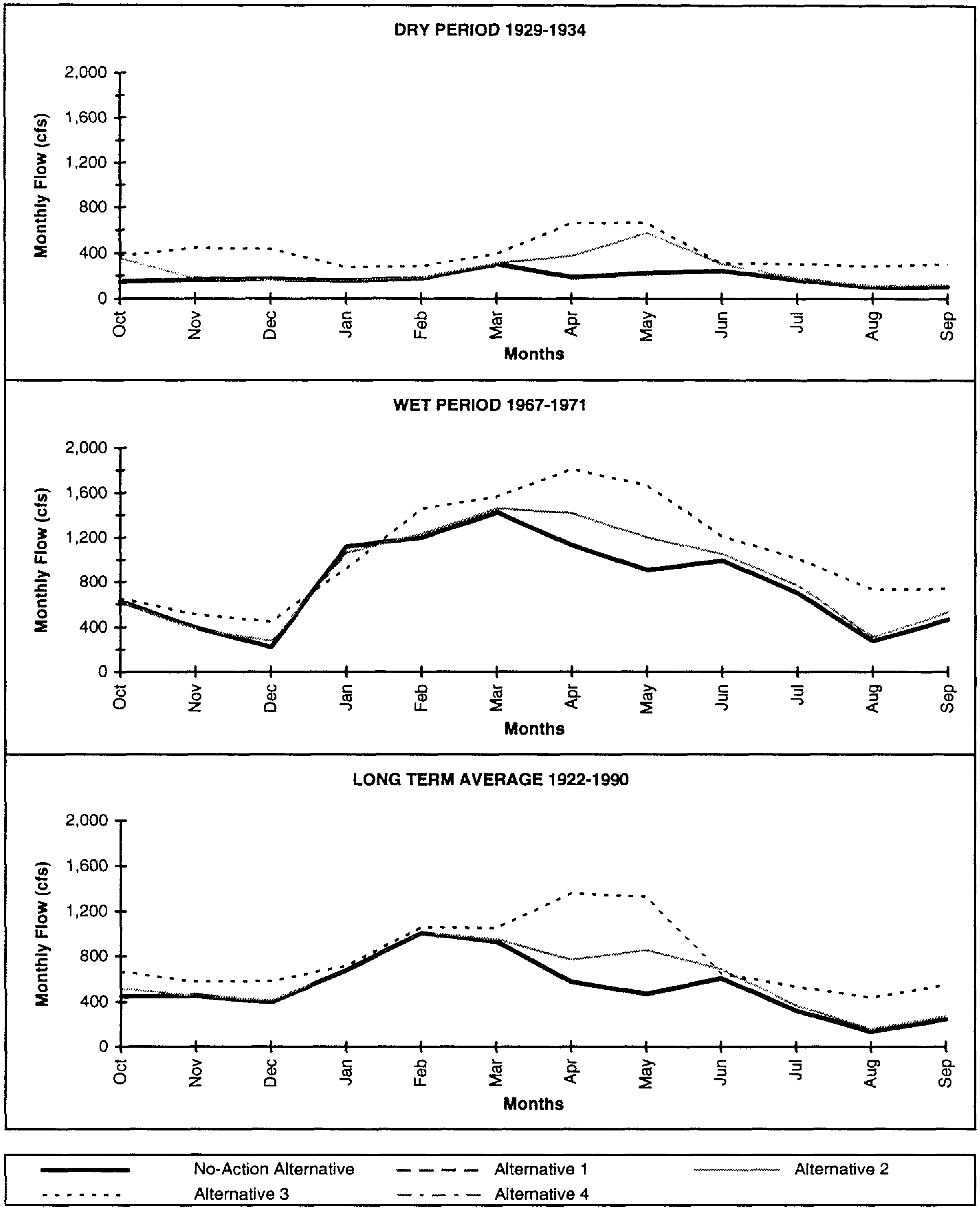
As a condition of water acquisition, it is assumed that the reduction in surface water deliveries to sellers cannot be offset with additional groundwater pumping, to prevent negative impacts to local groundwater supplies. Also, it is assumed that all water is acquired for instream flow and Delta outflow purposes. Therefore, none of the acquired water may be pumped by the CVP or SWP as it enters the Delta. It is recognized that this assumption, in practice, would require a SWRCB review process to establish instream flow and Delta outflow as beneficial uses of acquired water.

Merced River Below Crocker Huffman Diversion Dam. Based on the prioritization for the use of acquired water on the Merced River, as presented in Attachment G-4 of the Draft PEIS, the primary emphasis for use of acquired water in Alternative 2 is to help meet pulse flow objectives during April, May, and June. Simulated average monthly flows in the Merced River Below Crocker Huffman Diversion, shown in Figure III-46, illustrate an increase in spring flows under Alternative 2, as compared to the No-Action Alternative. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-47.

Tuolumne River Below La Grange Dam. The highest priority for the use of acquired water on the Tuolumne River flows is also to increase flows during April and May, with smaller increases in the summer months. Simulated average monthly flows in the Tuolumne River below La Grange Dam, shown in Figure III-48, illustrate an increase in spring flows under Alternative 2, as compared to the No-Action Alternative. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-49.

ALTERNATIVE 2 IMPACTS ON CVP OPERATIONS AND DELIVERIES

This section provides a comparison of conditions under Alternative 2 to the No-Action Alternative. The discussion focuses on reservoir operations, resulting releases, and deliveries of water to CVP contractors. A comparison of deliveries to CVP contractors in the Alternative 2 simulation, as compared to deliveries in the No-Action Alternative simulation is provided in Table III-13. Discussions of the operations of CVP facilities and deliveries to CVP contractors north of the Delta, south of the Delta, and on the Stanislaus River are provided in the following sections.



NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-46
MERCED RIVER BELOW CROCKER HUFFMAN
SIMULATED AVERAGE MONTHLY FLOWS

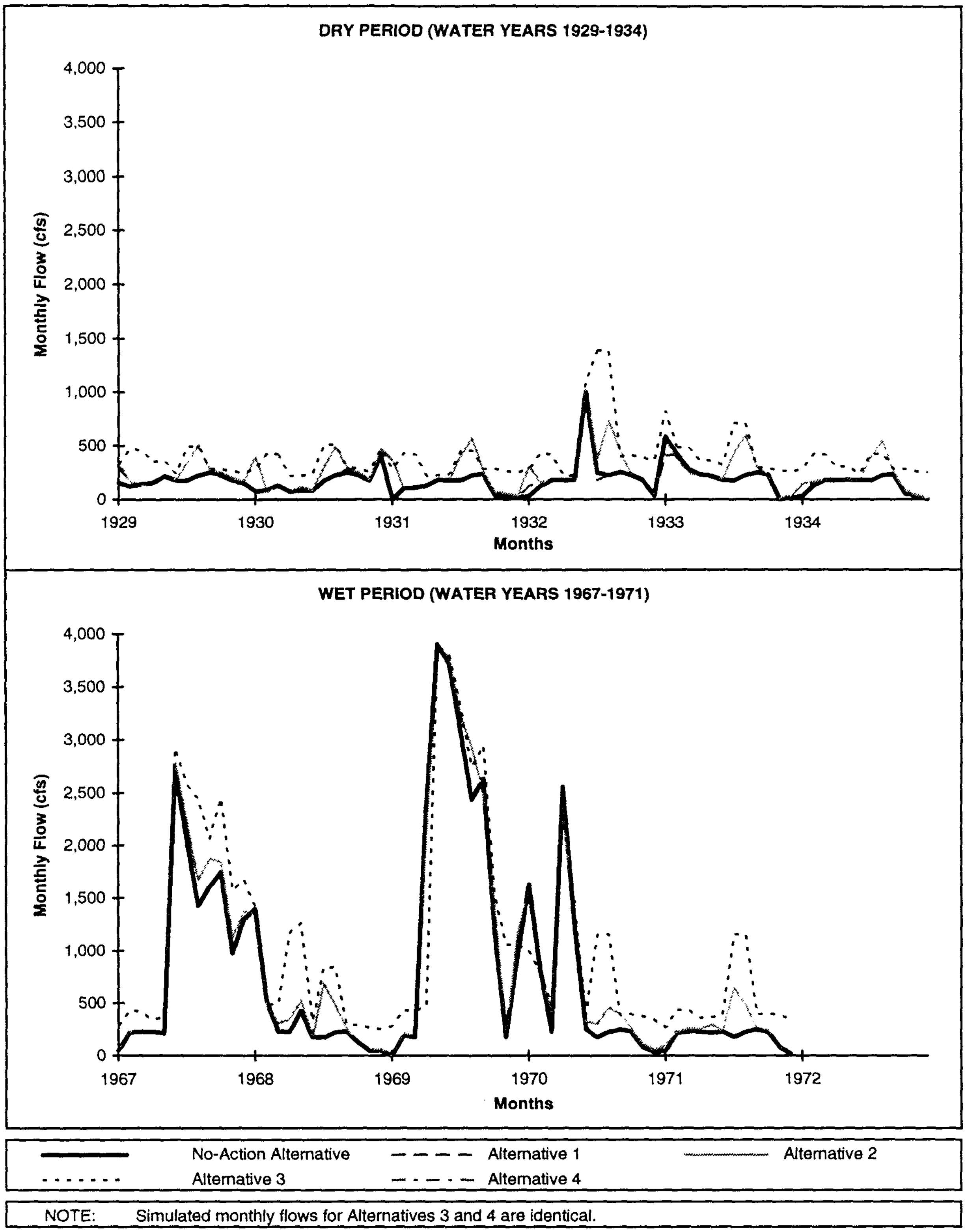
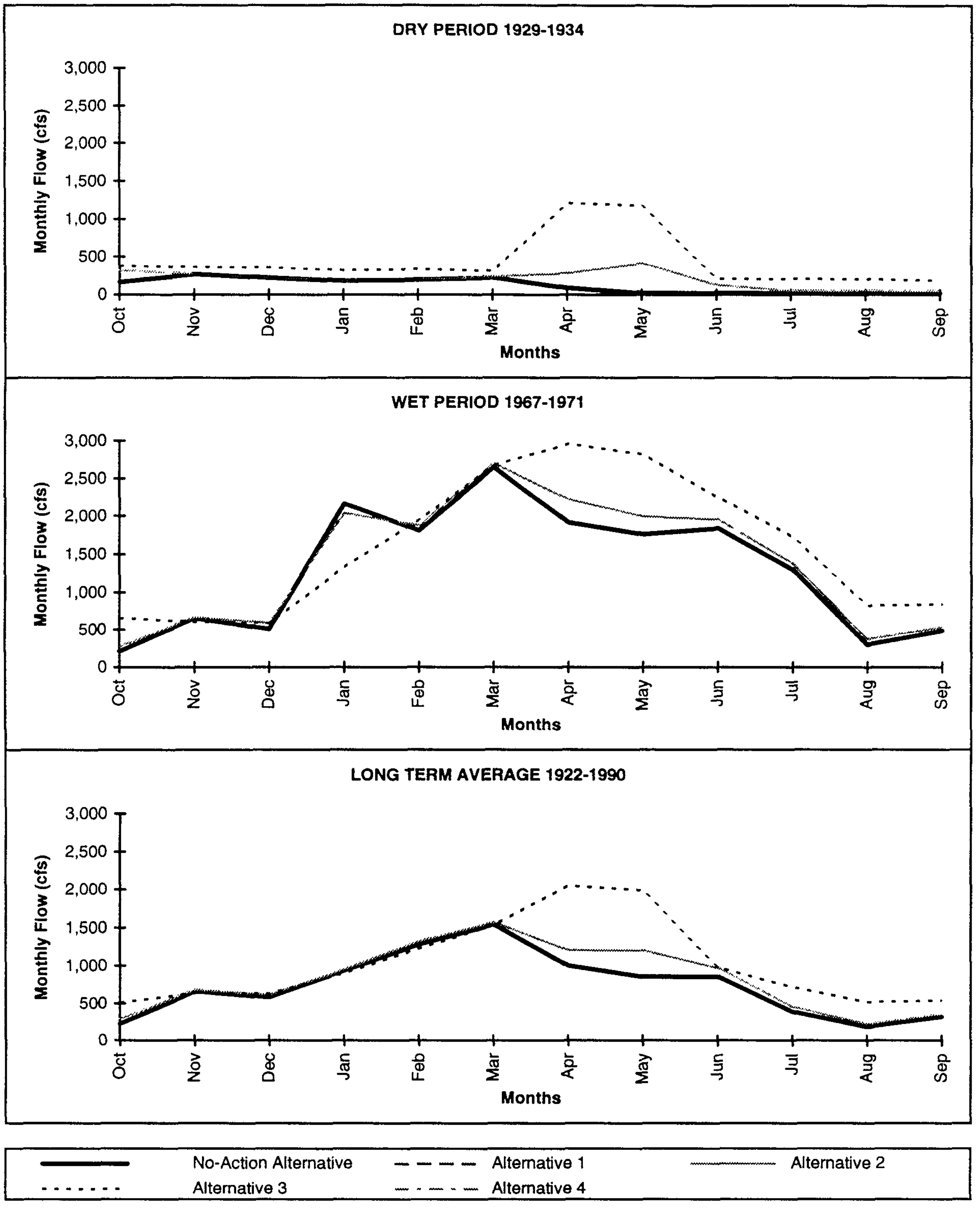


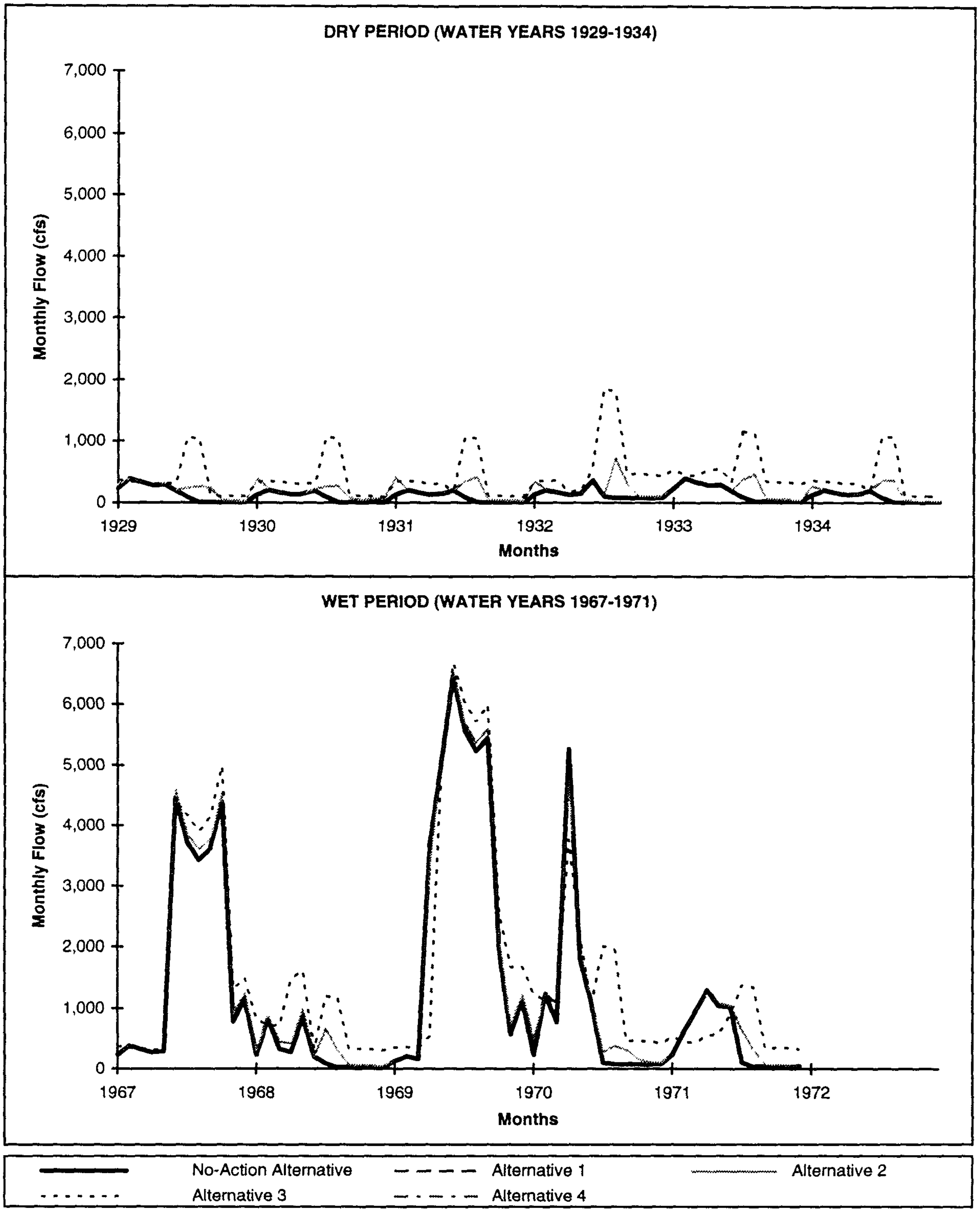
FIGURE III-47

MERCED RIVER BELOW CROCKER HUFFMAN SIMULATED MONTHLY FLOWS



NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-48
TUOLUMNE RIVER BELOW LAGRANGE
SIMULATED AVERAGE MONTHLY FLOWS



NOTE: Simulated monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-49

TUOLUMNE RIVER BELOW LAGRANGE SIMULATED MONTHLY FLOWS

TABLE III-13
COMPARISON OF CVP DELIVERIES IN THE ALTERNATIVE 2 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet)		Average Annual Change in CVP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 2	
1922 - 1990	Simulation Period	5,770	5,180	-590
1928 - 1934	Dry Period	4,560	3,940	-620
1967 - 1971	Wet Period	6,310	5,900	-410

NOTES:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.
(2) Alternative 2 assumes purchase of up to 130,000 acre-feet of water per year for level 4 refuges from the Sacramento River Water Rights and San Joaquin River Exchange Contractors.

CVP Operations

Under surface water acquisitions for target flows and refuge water supplies in Alternative 2, CVP reservoir operations and river flow regimes in the Trinity, Shasta, Sacramento, and West San Joaquin divisions would be similar to those described in Alternative 1. There would be a minor difference in operations due to the possible shift in reservoir releases for Level 4 refuge supplies. The Delta and Eastside divisions would be affected by the water acquisitions on the Stanislaus, Tuolumne, and Merced rivers to help meet target flows on these streams, and increase Delta outflow as described below.

Eastside Division. As described under the operations under Alternative 1, target flows on the Stanislaus River would be met in the July through March period through re-operation and the use of (b)(2) water. Therefore, acquired water would not be required after June to meet Alternative 2 target flows in later months. The acquisition and use of surface water on the Stanislaus River in Alternative 2 would result in little or no change in end-of-water year storage levels in New Melones Reservoir, as compared to Alternative 1 as shown in Figure III-2.

Under Alternative 2, acquired water would be released to increase stream flows in the Stanislaus River primarily in the April through June period, as shown in Figure III-12. On an average monthly basis, target flows would be met in nearly all months of above and below normal, dry, and critical year types. Although average monthly flows increase in the April through June period in wet year types, they would not meet the target flows.

The releases of acquired water on the Stanislaus, Tuolumne, and Merced rivers in the April through June period would result in increased flows in the San Joaquin River at Vernalis. Simulated average monthly flows in the San Joaquin River at Vernalis are shown in Figure III-14.

During July through March, average monthly flows under Alternative 2 would be similar to those in the No-Action Alternative.

Frequency distributions of simulated monthly water quality on the San Joaquin River at Vernalis during the irrigation and non-irrigation seasons are shown in Figure III-16. Under Alternative 2 operations, water quality at Vernalis would exceed the applicable water quality standards in approximately the same number of months during the simulation period, as in the No-Action Alternative. During the irrigation season, water quality would be at concentrations below the standard (improved water quality) more frequently under Alternative 2, as compared to the No-Action Alternative. The water quality standard would be exceeded less frequently during the non-irrigation season than under the No-Action Alternative.

Delta Division. Releases of acquired water during April and May would provide increased flows at Vernalis, which would contribute toward meeting the Bay-Delta Plan Accord pulse flow requirements. In Alternative 2, the increase in Delta inflow from the San Joaquin River would not be exported by the CVP or SWP. Therefore, the additional inflows would contribute directly to Delta outflow, increasing average annual Delta outflow by about 80,000 acre-feet per year.

Friant Division. Because the objectives in Alternative 2 would not affect operations of Millerton Lake, Friant Division operations would be similar to the No-Action Alternative.

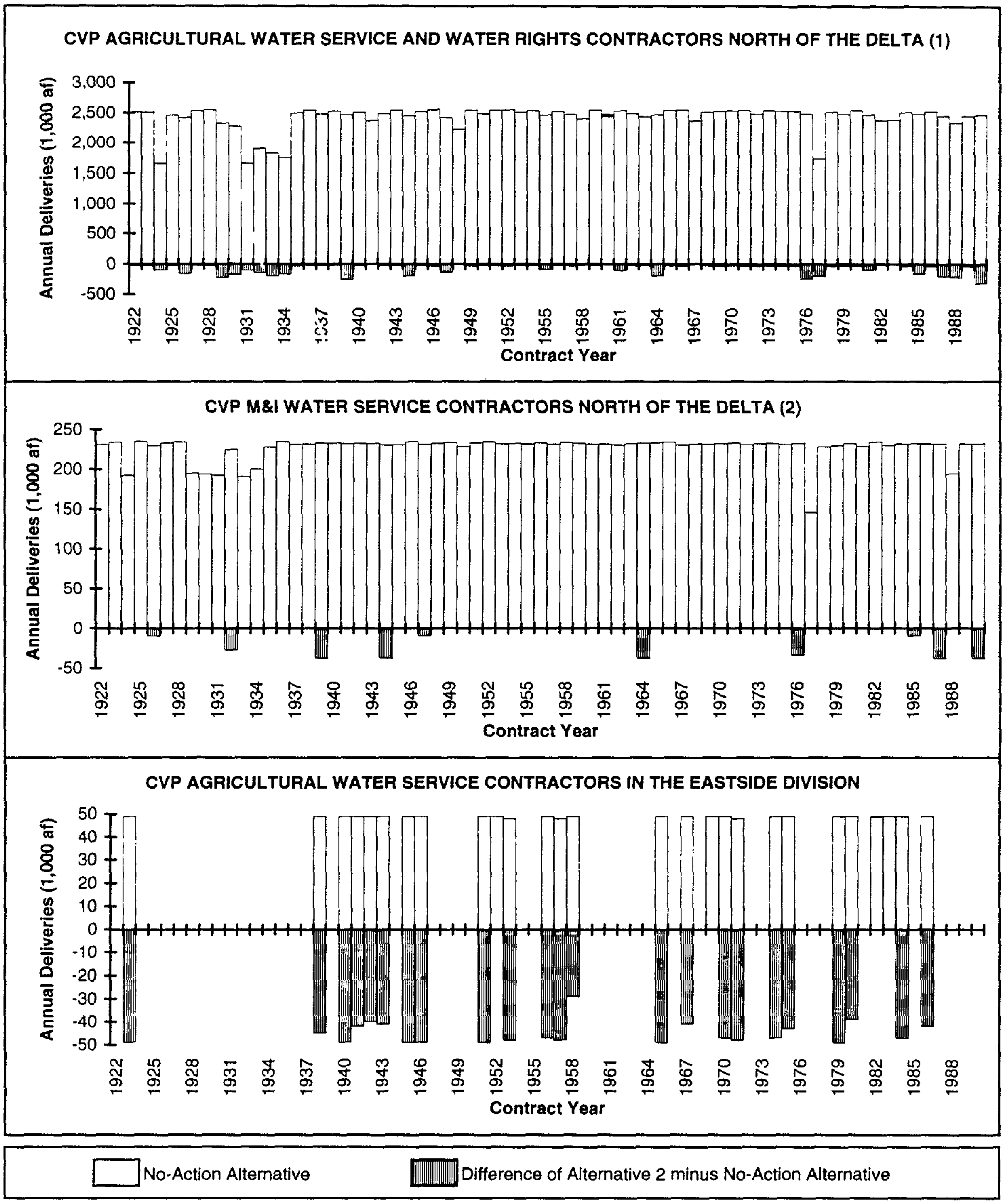
CVP Deliveries

In Alternative 2, water would be acquired from willing sellers for delivery to refuges and for release toward meeting the target flows. The release of acquired water on the Stanislaus, Tuolumne, and Merced rivers would not be available for export because this water would be released for both instream flow needs and for Delta outflow purposes The amount of water that would be available for delivery to the CVP contractors would not be affected, except for the small amount that is assumed to be acquired from willing sellers for Level 4 refuge supplies.

CVP Water Deliveries North and South of the Delta. Deliveries to CVP Sacramento River Water Rights Contractors and San Joaquin River Exchange Contractors would be similar to those described in the No-Action Alternative. Deliveries to CVP agricultural and M&I water service contractors north and south of the Delta would be similar to those in Alternative 1, as shown in Figures III-2, III-50, and III-51.

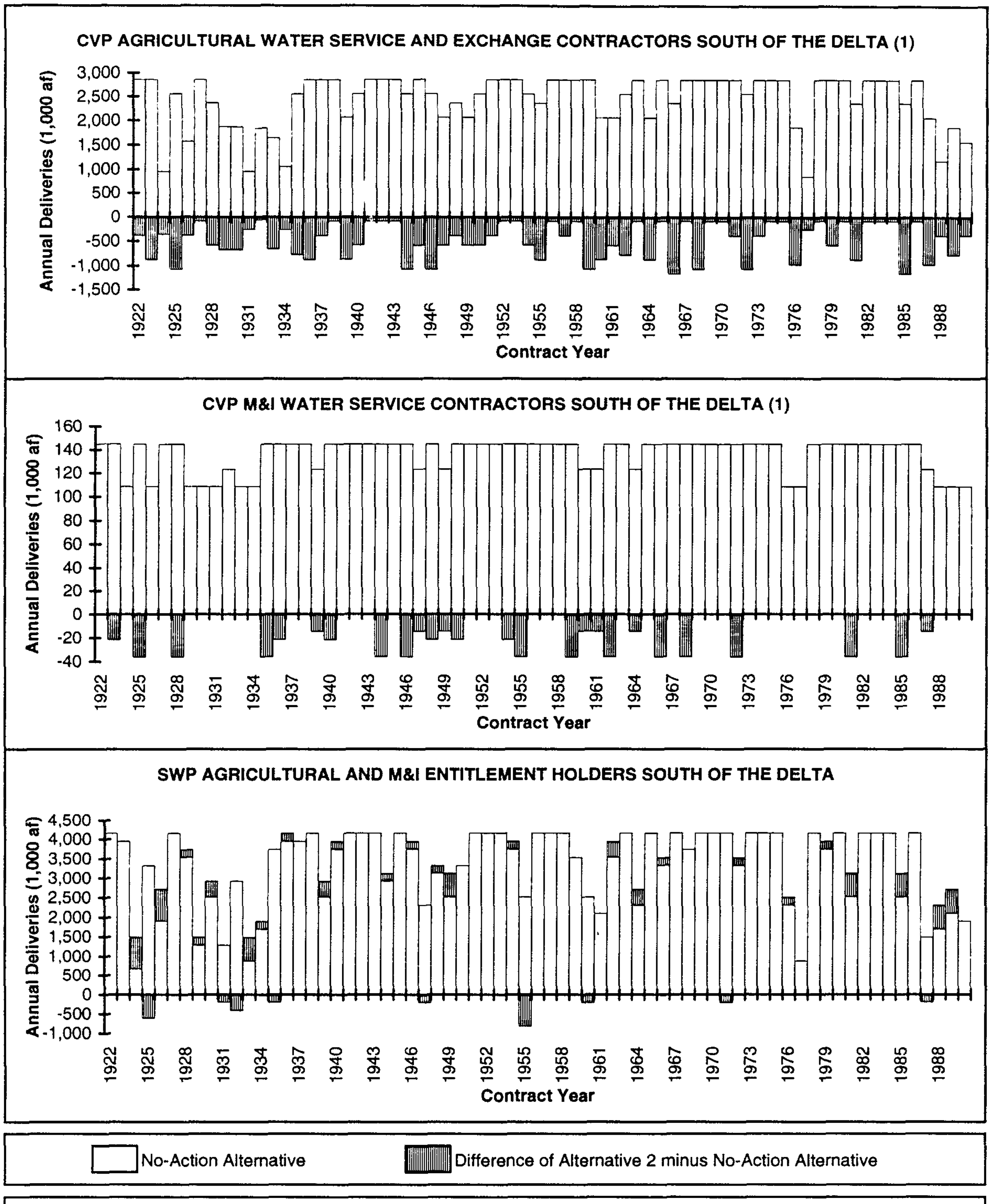
CVP Water Deliveries Eastside Division. The deliveries to CVP agricultural water service contractors on the Stanislaus River in Alternative 2 would be similar to those described in Alternative 1.

CVP Water Deliveries To Refuges. Alternative 2 includes annual deliveries of Level 4 water supplies to refuges as shown in Figure III-24, in comparison to the No-Action Alternative.



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-50
SIMULATED ALTERNATIVE 2 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-51
SIMULATED ALTERNATIVE 2 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990

ALTERNATIVE 2 IMPACTS ON SWP OPERATIONS AND DELIVERIES

In Alternative 2, it is assumed that the SWP would not participate as a willing seller. In addition, the release of acquired water would be prescribed for instream and Delta outflow purposes. Therefore, the impacts to the SWP in Alternative 2 would be similar to the impacts associated with Alternative 1. A comparison of average annual SWP deliveries in Alternative 2 and in the No-Action Alternative is provided in Table III-14.

TABLE III-14
COMPARISON OF SWP DELIVERIES IN THE ALTERNATIVE 2 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual SWP Deliveries (1,000 acre-feet)		Average Annual Change in SWP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 2	
1922 - 1990	Simulation Period	3,330	3,410	+80
1928 - 1934	Dry Period	2,050	2,190	+140
1967 - 1971	Wet Period	4,140	4,070	-70

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

SWP Operations

Releases from Lake Oroville to the Feather River and flows on the Feather River below Nicolaus would be similar to those described in Alternative 1. Exports through Banks Pumping Plant would also be similar to those described for Alternative 1.

SWP Entitlement Water Deliveries

As described above, the delivery of water to SWP entitlement holders under Alternative 2 would be similar to those described in Alternative 1.

ALTERNATIVE 3

DESCRIPTION OF ALTERNATIVE

Water management provisions in Alternative 3 include all of the provisions included in Alternative 1, as well the acquisition of surface water from willing sellers toward meeting Level 4 water supplies for refuges, and the acquisition of water for increasing instream flows toward flow targets identified in Attachment G-4 to the Draft PEIS. Water would be acquired to improve instream flow conditions on the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Yuba rivers. Under Alternative 3, water acquired for instream purposes may be exported by the CVP and SWP when it flows into the Delta.

The Re-operation and (b)(2) Water Management components of Alternative 3 would be similar to these components in Alternative 1. In Alternative 3, (b)(2) water is used for upstream actions on CVP-controlled rivers only, and towards meeting 1995 Water Quality Control Plan requirements.

Similar to Alternative 1, the CVP would be operated under Alternative 3 in an attempt to increase end-of-month storage in September in Shasta and Folsom lakes to provide increased river releases during the fall in the Sacramento and American rivers. As compared to the No-Action Alternative, increased reservoir releases would also be made from Whiskeytown Lake to increase Clear Creek minimum flows year round, and from New Melones Reservoir to provide higher flows on the Stanislaus River to attempt to meet target flows. An increase in Clair Engle Lake releases, to meet increased Trinity River flow releases in this alternative, would result in a decrease in spring and early summer diversions to the Sacramento River. Also similar to Alternative 1, Alternative 3 includes implementation of the habitat restoration actions.

WATER ACQUISITION IN ALTERNATIVE 3

As indicated above, in addition to water acquired for Level 4 refuges, water would be acquired in Alternative 3 for instream flow purposes on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba rivers. A description of the assumptions for the acquisition of water in Alternative 3 is provided below.

Water Acquisition for Level 4 Refuge Water Supplies

Water acquisition in Alternative 3 includes the acquisition of the same quantities of water from the same sources to provide Level 4 refuge water supplies as described in Alternative 2.

Water Acquisition for Instream Flows

In Alternative 3, surface water would be acquired from willing sellers on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba rivers for instream flow purposes. The methodology regarding the management and release of acquired water under Alternative 2 would also be applied to water acquisitions in Alternative 3.

In Alternative 3, maximum acquisition quantities for instream flows on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba rivers are shown in Table III-12. It is assumed that water would be acquired from water rights holders on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba rivers that possess storage and diversion rights on these rivers. The acquired water would be stored during the period of a contract year, and released in a manner to increase flows toward the instream flow targets on these rivers. In effect, the acquisition of water would involve a shift in the release pattern from storage reservoirs, combined with a reduction in the diversion of the released water. It is assumed that acquired water would be stored and released from New Melones Reservoir on the Stanislaus River, New Don Pedro Reservoir on the Tuolumne River, Lake McClure on the Merced River, New Hogan Reservoir on the Calaveras River, Camanche Reservoir on the Mokelumne River, and New Bullards Bar Reservoir on the Yuba River.

Merced River Below Crocker Huffman Diversion Dam. The use of acquired water on the Merced River under Alternative 3 would result in increased flows in all months with the primary emphasis in April and May, as compared to the No-Action Alternative as shown Figure III-46. During the wet period of 1967-1971, a slight reduction in average flows during January would occur under Alternative 3, as compared to the No-Action Alterative, primarily as a result of reduced storage conditions that would decrease winter flood control releases. During dry periods, flows would increase in all months. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-47.

Tuolumne River Below La Grange Dam. Tuolumne River flows would also be increased in April through May, with smaller increases in the summer months. As shown in Figure III-48, flows would be increased primarily during the April-May spring pulse flow period. Reduced storage levels would reduce required releases for flood control in January. During dry periods, flows would increase in all months. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-49.

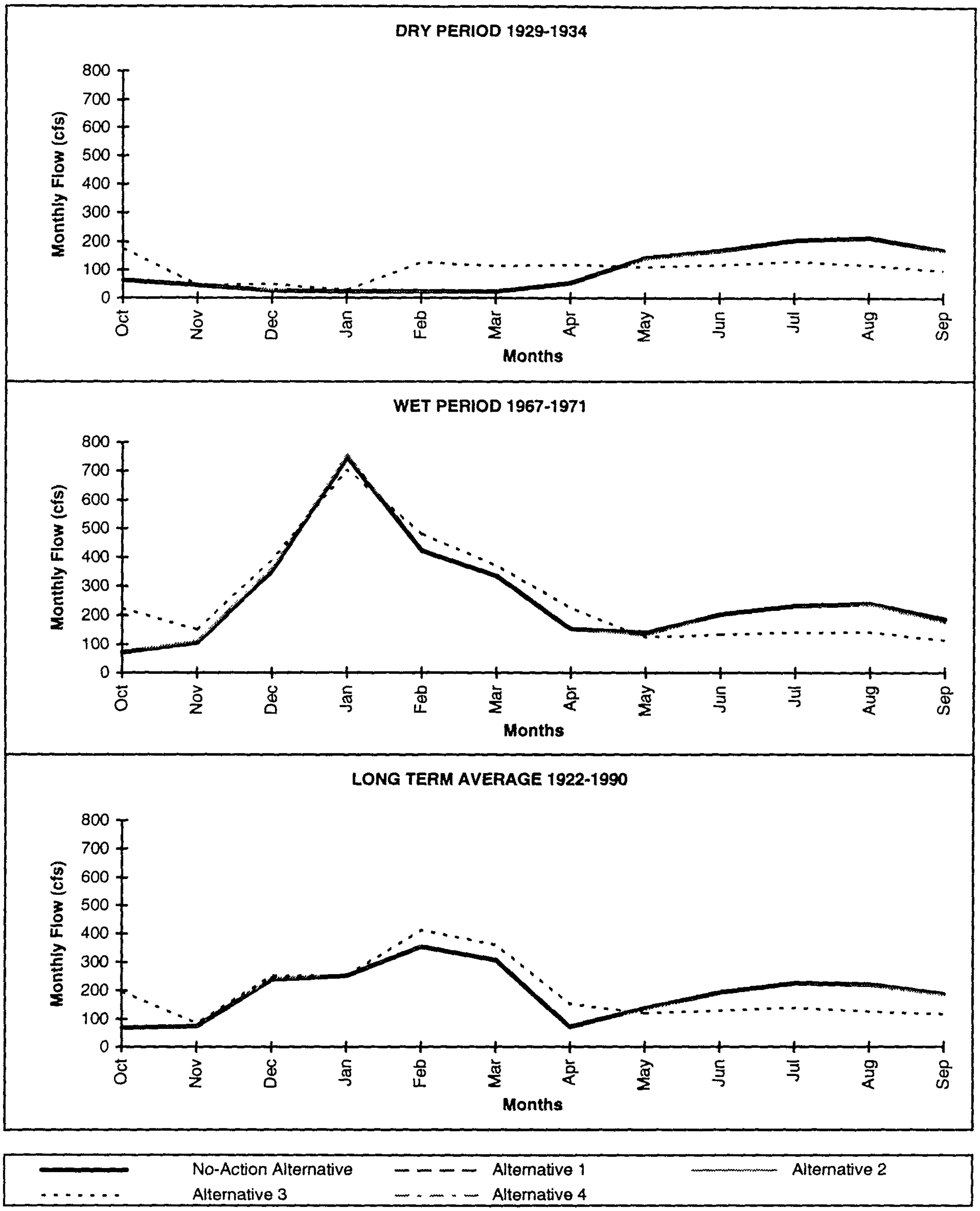
Stanislaus River at Goodwin Dam. The acquired water on the Stanislaus River would be used primarily to increase spring pulse flows. As shown of Figure III-12, simulated monthly flows below Goodwin Dam under Alternative 3 would increase in April through June, with additional increases through the fall and winter months as compared to the No-Action Alternative. As discussed in the section addressing CVP operations, the increased Stanislaus River flows under Alternative 3 would occur from the combination of acquired water, re-operation of New Melones Reservoir, and a revised (b)(2) Water Management, as compared to Alternative 1. The opportunity for re-operation of New Melones Reservoir and a revised (b)(2) Water Management under Alternative 3 would occur due to increased San Joaquin River flows that would result from the release of acquired water on the Merced and Tuolumne rivers.

Figures III-12 and III-13 indicate that the use of acquired water in accordance with biological priorities under Alternative 3 would result in flows below Goodwin Dam greater than 1,500 cfs more frequently than under the No-Action Alternative, or under Alternatives 1 and 2. Historical operations have indicated that flows above 1,500 cfs in this portion of the Stanislaus River can cause seepage and flooding problems to lands adjacent to the river.

Calaveras River at New Hogan Dam. The flow targets on the Calaveras River in Alternative 3 were established for the reach between New Hogan Dam and the Bellota Weir. This section of the river conveys releases for downstream agricultural diversion during the summer months. Consequently, the acquisition of water from downstream diversion demands enables the releases to be rescheduled, but would not result in an increase in total annual flow in this section of the river. As shown in Figure III-52, flows on the Calaveras River would increase in the winter and early spring months and decrease in the summer and fall months under Alternative 3 with the use of acquired water. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-53.

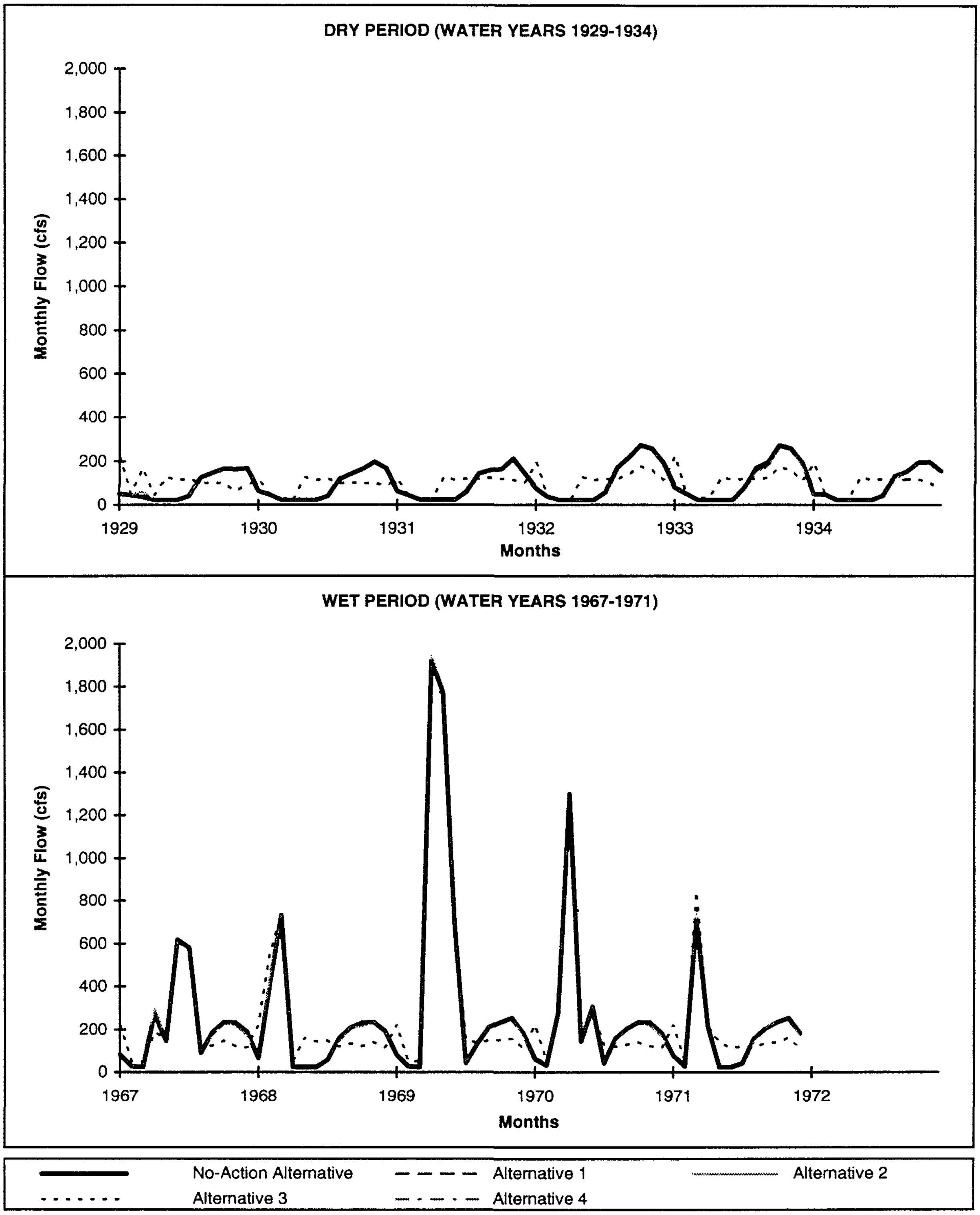
Mokelumne River at Woodbridge. On the Mokelumne River, releases of acquired water would result in increased flows in the fall through spring periods, with the greatest increases in April and May. As shown in Figure III-54, flows during dry years would not change, due to the limited acquisition quantities during dry years. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-55.

Yuba River at Marysville. On the Yuba River, releases from New Bullards Bar Reservoir and downstream diversions would be re-operated to provide water toward the flow targets under Alternative 3. As shown in Figure III-56, the releases of acquired water would result in increased flows in the spring, summer, and fall months, as compared to flows under the No-Action Alternative. Monthly flows during dry and wet portions of the simulation period are shown in Figure III-57.



NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

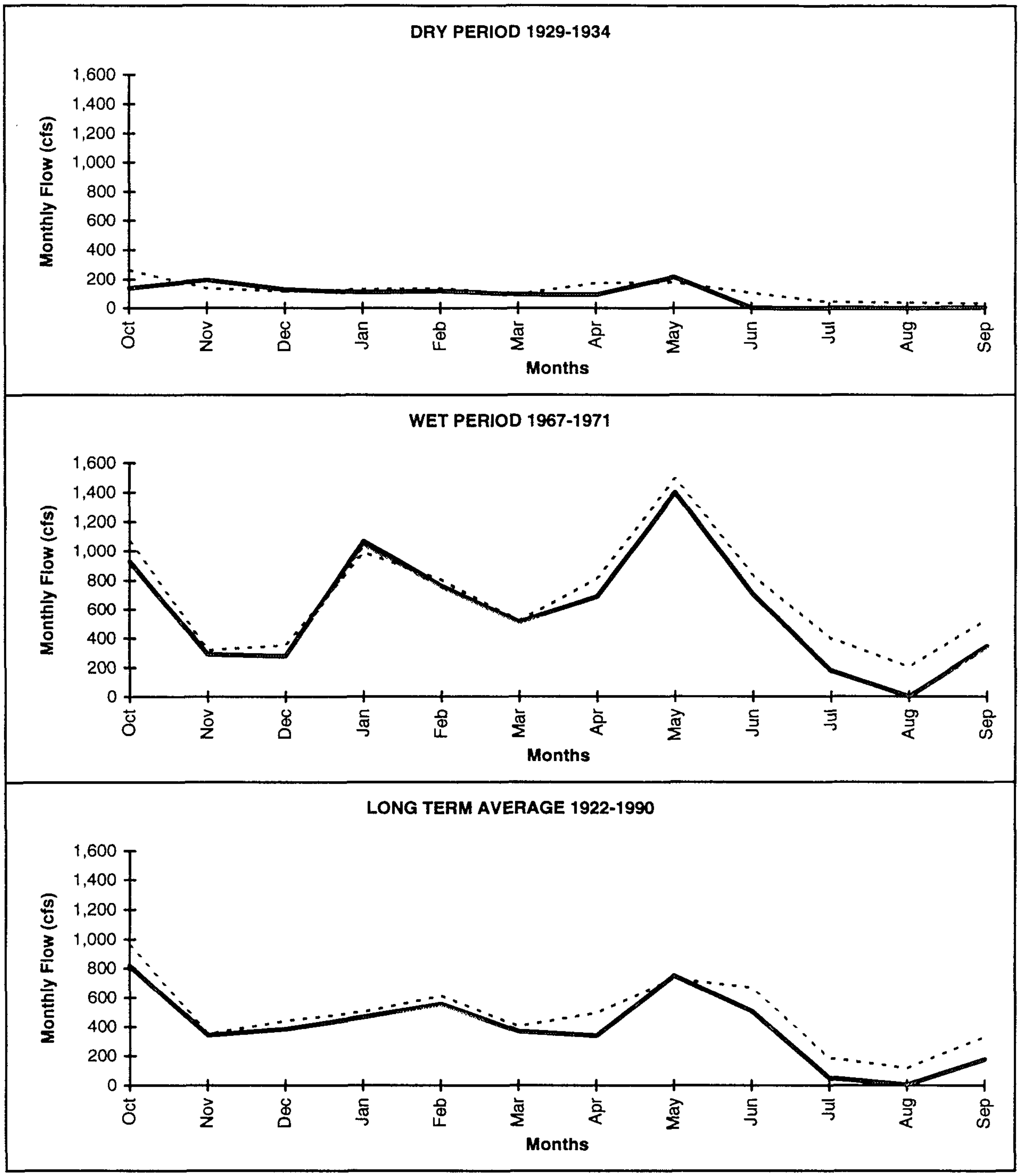
FIGURE III-52
CALAVERAS RIVER BELOW NEW HOGAN
SIMULATED AVERAGE MONTHLY FLOWS



NOTE: Simulated monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-53

CALAVERAS RIVER BELOW NEW HOGAN SIMULATED MONTHLY FLOWS



———	No-Action Alternative	— — — —	Alternative 1	············	Alternative 2
- - - - - - -	Alternative 3	— - — - —	Alternative 4		

NOTE: Simulated average monthly flows for Alternatives 3 and 4 are identical.

FIGURE III-54
MOKELUMNE RIVER BELOW WOODBRIDGE
SIMULATED AVERAGE MONTHLY FLOWS

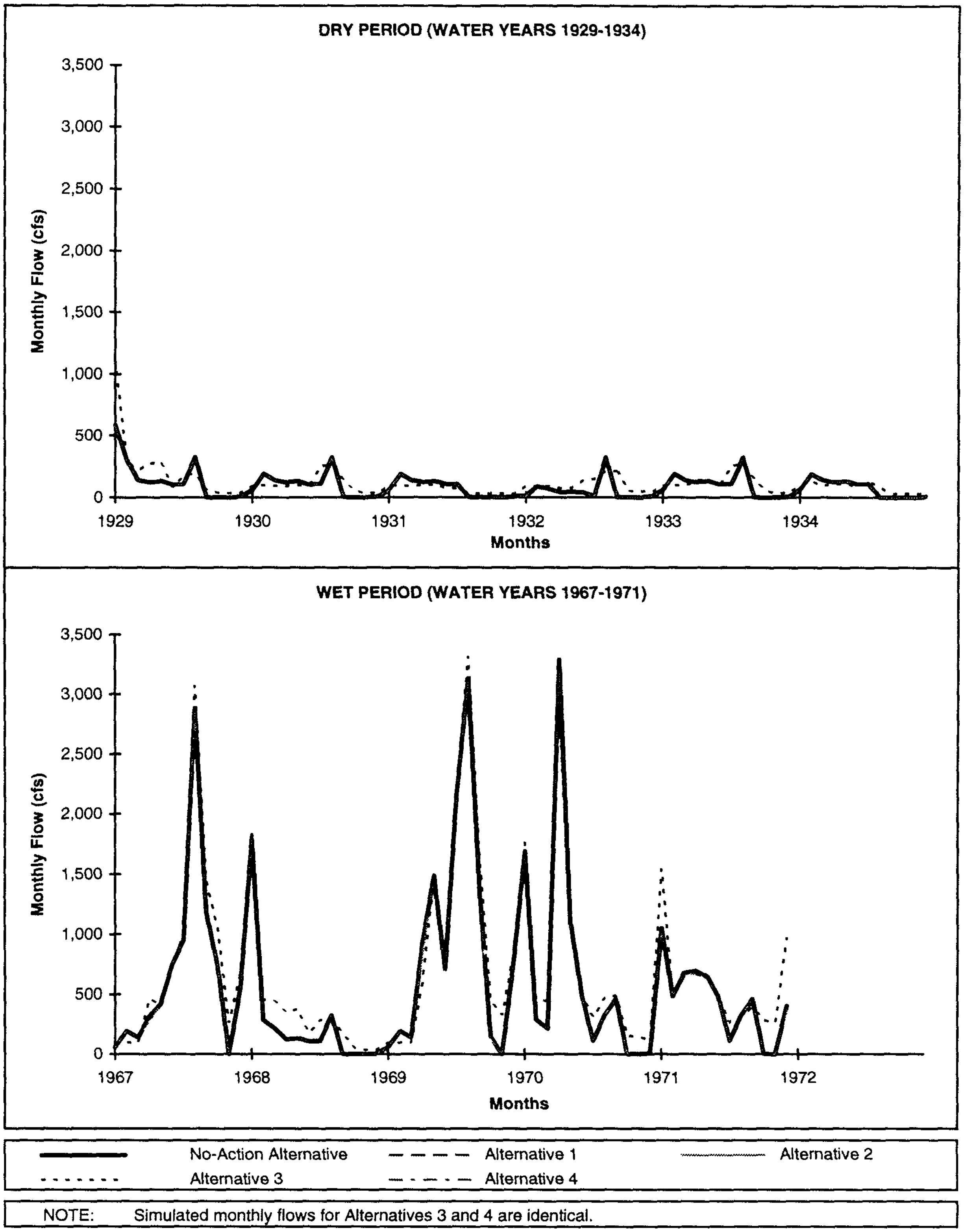


FIGURE III-55

MOKELUMNE RIVER BELOW WOODBRIDGE SIMULATED MONTHLY FLOWS

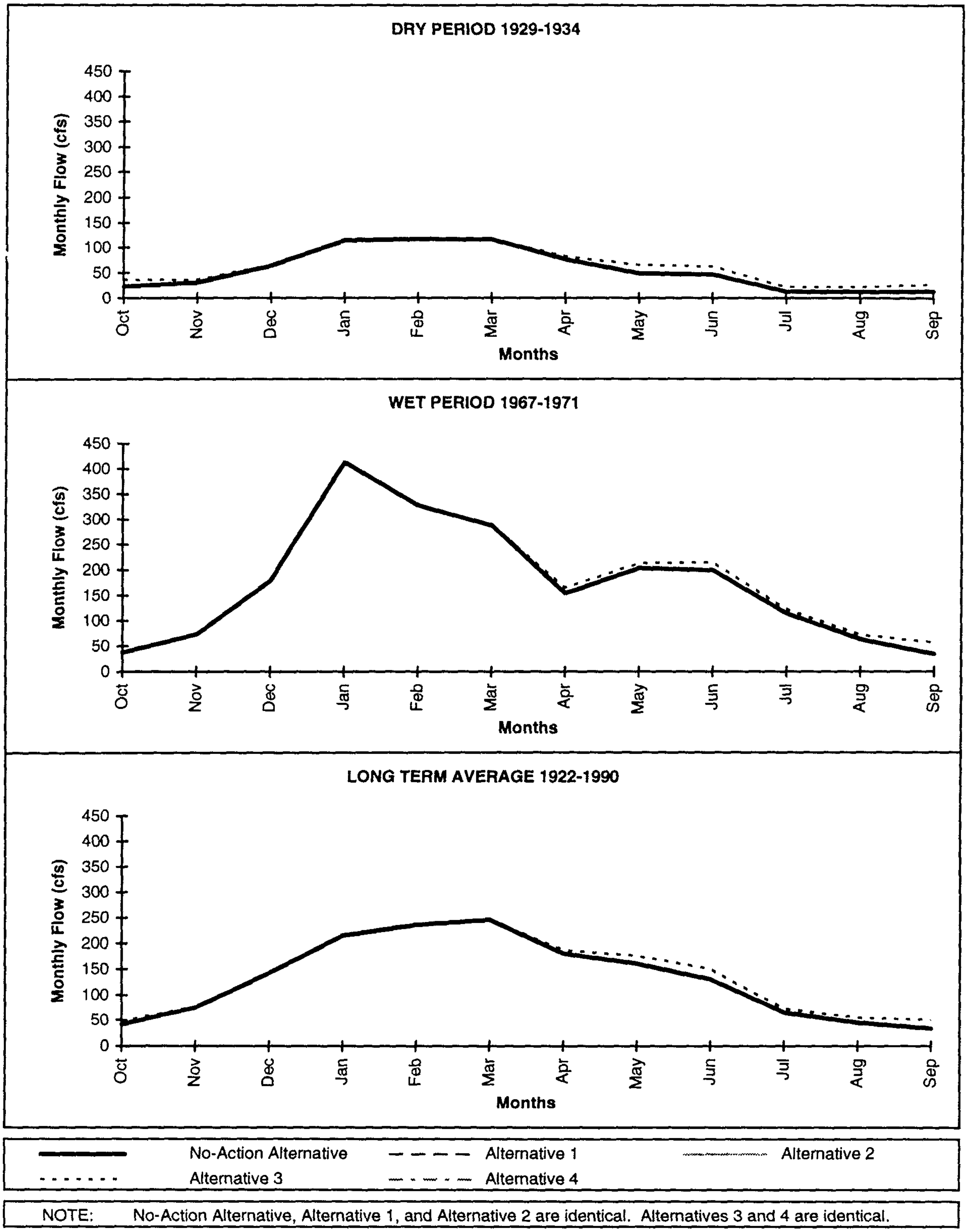
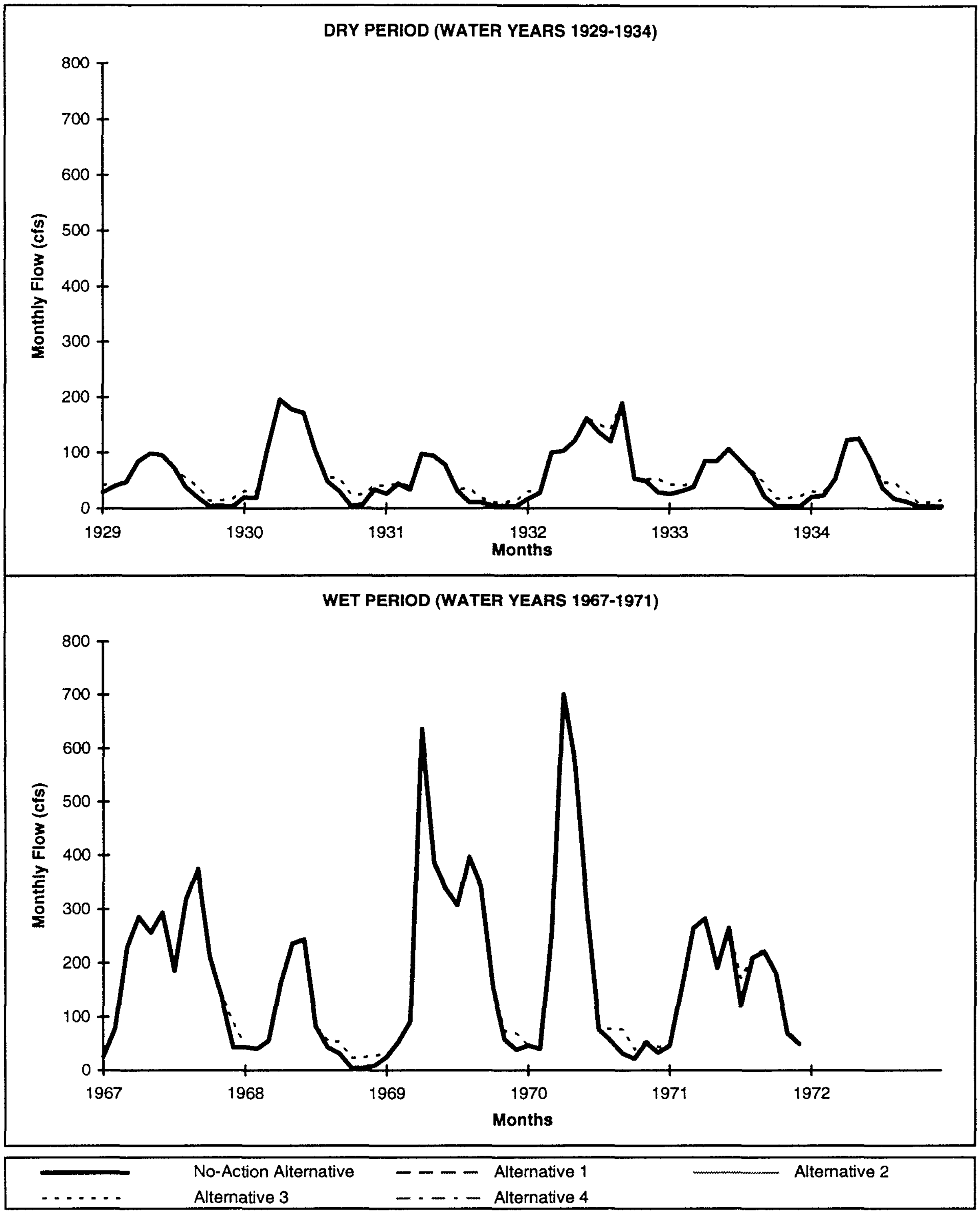


FIGURE III-56

YUBA RIVER AT MARYSVILLE SIMULATED AVERAGE MONTHLY FLOWS



NOTE: No-Action Alternative, Alternative 1, and Alternative 2 are identical. Alternatives 3 and 4 are identical.

FIGURE III-57

YUBA RIVER AT MARYSVILLE SIMULATED MONTHLY FLOWS

ALTERNATIVE 3 IMPACTS ON CVP OPERATIONS AND DELIVERIES

Alternative 3 CVP operations and water deliveries would be similar to those described in Alternative 1. Changes in delivery of water to CVP contractors between Alternative 3 and the No-Action Alternative are summarized in Table III-15. A brief summary of CVP operations and deliveries is provided below.

TABLE III-15
COMPARISON OF CVP DELIVERIES IN THE ALTERNATIVE 3 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet): No-Action Alternative	Simulated Average Annual CVP Deliveries (1,000 acre-feet): Alternative 3	Average Annual Change in CVP Deliveries (1,000 acre-feet)
1922 - 1990	Simulation Period	5,770	5,380	-390
1928 - 1934	Dry Period	4,560	4,220	-340
1967 - 1971	Wet Period	6,310	6,010	-300

NOTES:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.
(2) Alternative 3 assumes purchase of up to 130,000 acre-feet of water per year for level 4 refuges from the Sacramento River Water Rights and San Joaquin River Exchange Contractors.

CVP Operations

In Alternative 3, CVP operations in the Trinity, Shasta, Sacramento River, and American River divisions would be similar to Alternative 1. Friant Division operations would be similar to the No-Action Alternative. However, CVP operations in the Delta, Eastside, and West San Joaquin Divisions would be affected due to higher San Joaquin River flows and the ability to export acquired water through Tracy Pumping Plant once it reaches the Delta. The operations of these divisions are discussed below.

Eastside Division. Frequency distributions of simulated end-of-water year storages in New Melones Reservoir are presented in Figure III-2. As shown on this figure, reservoir storages in Alternative 3 are generally lower than storage levels in the No-Action Alternative, except during periods of near flood control storage levels, where the frequency is increased. Storage levels under Alternative 3 are generally higher than storage levels under Alternative 1. The increase in storage levels results from a combination of improved flexibility in the operation of New Melones Reservoir due to higher flows on the San Joaquin River upstream of the Stanislaus River, and the management of acquired water.

The additional flow in the San Joaquin River due to the release of acquired water on both the Merced and Tuolumne rivers would result in improved water quality conditions at Vernalis as compared to the No-Action Alternative. The improvement in San Joaquin River water quality would reduce the quantity of required releases from New Melones Reservoir necessary to maintain water quality conditions at Vernalis. As a result, New Melones Reservoir operations under Alternative 3 result in increasing the frequency that target flows on the Stanislaus River would be met through re-operation and (b)(2) Water Management. The combination of re-operation of New Melones Reservoir and the management of acquired water would result in greater releases during spring months and lower storage levels during summer months. In some years, end-of-year storage levels in New Melones Reservoir would be slightly higher than storage levels in Alternative 1, because a portion of the acquired water would be held in storage for subsequent release in October through December.

The combined contribution of acquired water released on the Merced, Tuolumne, and Stanislaus rivers would result in increased flow in the San Joaquin River at Vernalis, as shown in Figure III-14. On an average monthly basis, flows in the San Joaquin River at Vernalis would increase in nearly all months, with the largest increases during April and May. The increased flow would also result in improved monthly water quality conditions, as shown in Figure III-16. Under Alternative 3, water quality conditions at Vernalis would meet the monthly standards during both the irrigation and non-irrigation seasons in nearly all months of the simulation period.

Delta Division. As a result of upstream water acquisitions, simulated Delta inflows increase by about 400,000 acre-feet per year in Alternative 3 as compared to the No-Action Alternative. In Alternative 3 this additional inflow may be exported by the CVP and SWP, as available under the COA. Figure III-18 shows a comparison of the frequency distributions for simulated Tracy Pumping Plant annual exports. Tracy Pumping Plant exports decrease by about 90,000 acre-feet per year as compared to the No-Action Alternative, and increase by about 170,000 acre-feet per year as compared to Alternative 1. The CVP ability to export the acquired water is limited because the majority of the acquired water is released in the fall and the spring when Tracy Pumping Plant is already pumping at maximum regulatory or physical capacity. In addition, CVP releases from upstream reservoirs cannot be reduced to take advantage of acquired water in the Delta, since (b)(2) water must be released in the fall and spring for upstream flow objectives. Figure III-17 shows the change in average monthly exports as compared to the No-Action Alternative.

Simulated Delta outflow increases by about 200,000 acre-feet per year as compared to the No-Action Alternative. Average monthly Delta outflows in the No-Action Alternative and Alternative 3 simulations are presented in Figure III-19.

West San Joaquin Division. Operations of the CVP portion of San Luis Reservoir are similar to Alternative 1. As shown in comparison in Figure III-18, Alternative 3 simulated average monthly storage is greater than in the No-Action Alternative, due to a combination of higher fall exports as part of (b)(2) Water Management and higher spring exports of acquired water.

CVP Contract Water Deliveries

In Alternative 3, water would be acquired from willing sellers for delivery to refuges and for release toward meeting the flow objectives. The acquired water released on the Stanislaus, Tuolumne, Merced, Calaveras, Mokelumne, and Yuba rivers would be available for export when it reaches the Delta. As described above, the CVP's ability to export acquired water is limited due to timing, and physical and regulatory limitations. The resulting changes in CVP deliveries are discussed below.

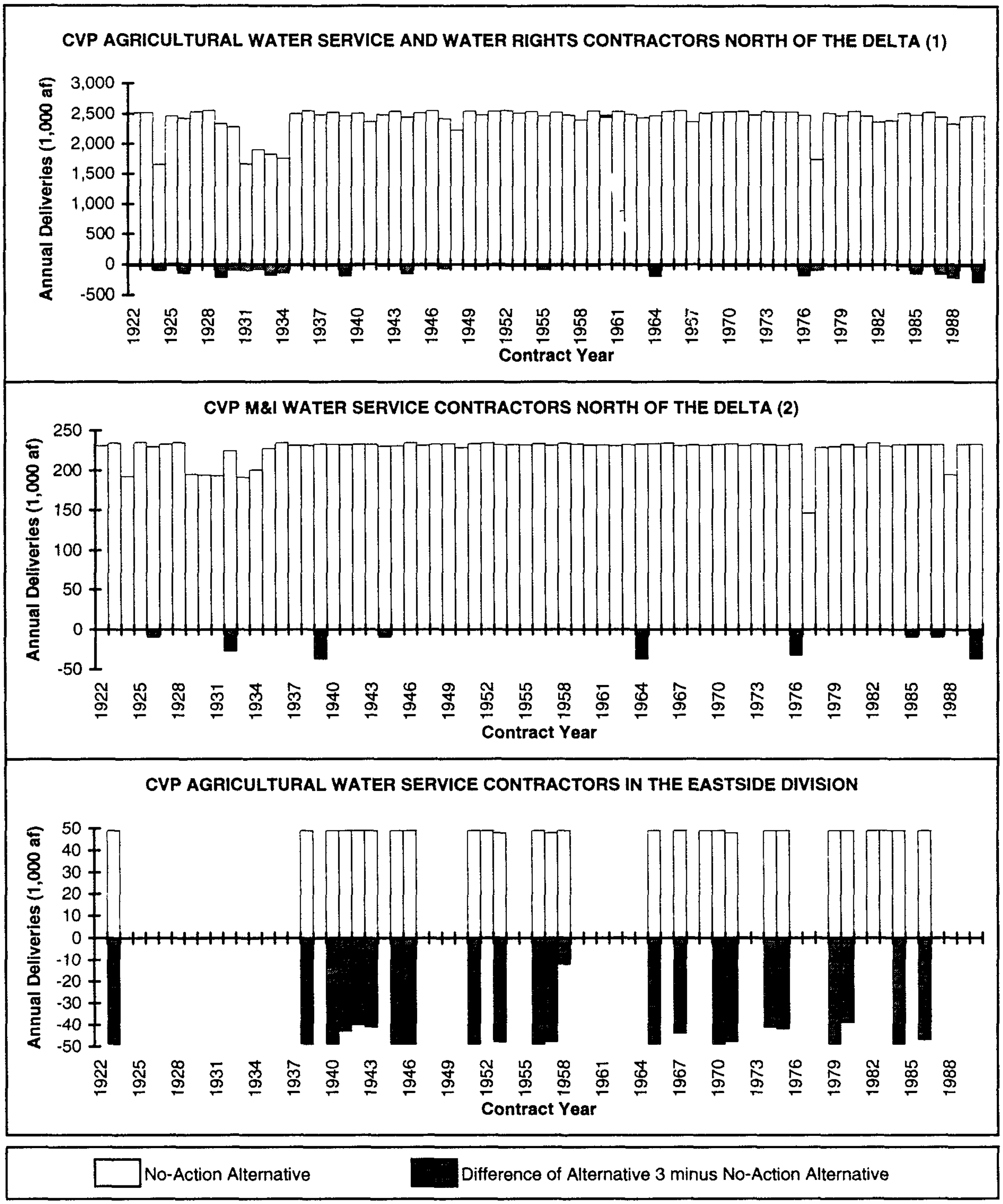
CVP Water Deliveries North of the Delta. Deliveries to CVP Sacramento River Water Rights Contractors would be similar to those described in the No-Action Alternative. Deliveries to CVP agricultural and M&I water service contractors north of the Delta would be similar to those in Alternative 1, as shown in Figure III-58.

CVP Water Deliveries Eastside Division. As described above, the increased flow in the San Joaquin River above the confluence with the Stanislaus River, due to water acquisition on the Tuolumne and Merced rivers, would improve San Joaquin River water quality. This would reduce the quantity of water required from New Melones Reservoir to maintain water quality conditions at Vernalis, and would enable greater releases to the Stanislaus River as part of (b)(2) Water Management.

The (b)(2) Water Management operation of New Melones Reservoir under in Alternative 3 would result in similar deliveries to CVP agricultural water service contractors based on firm water supply as under the (b)(2) Water Management operation described in Alternative 1, as shown in Figure III-58. However, this revised operation, in combination with releases of acquired water from New Melones Reservoir, would result in lower storage levels during the spring and summer months, and would reduce the frequency of snow-melt induced flood control releases. Consequently, opportunities for delivery to CVP contracts based on an interim water supply would be reduced, as compared to the No-Action Alternative and to Alternative 1.

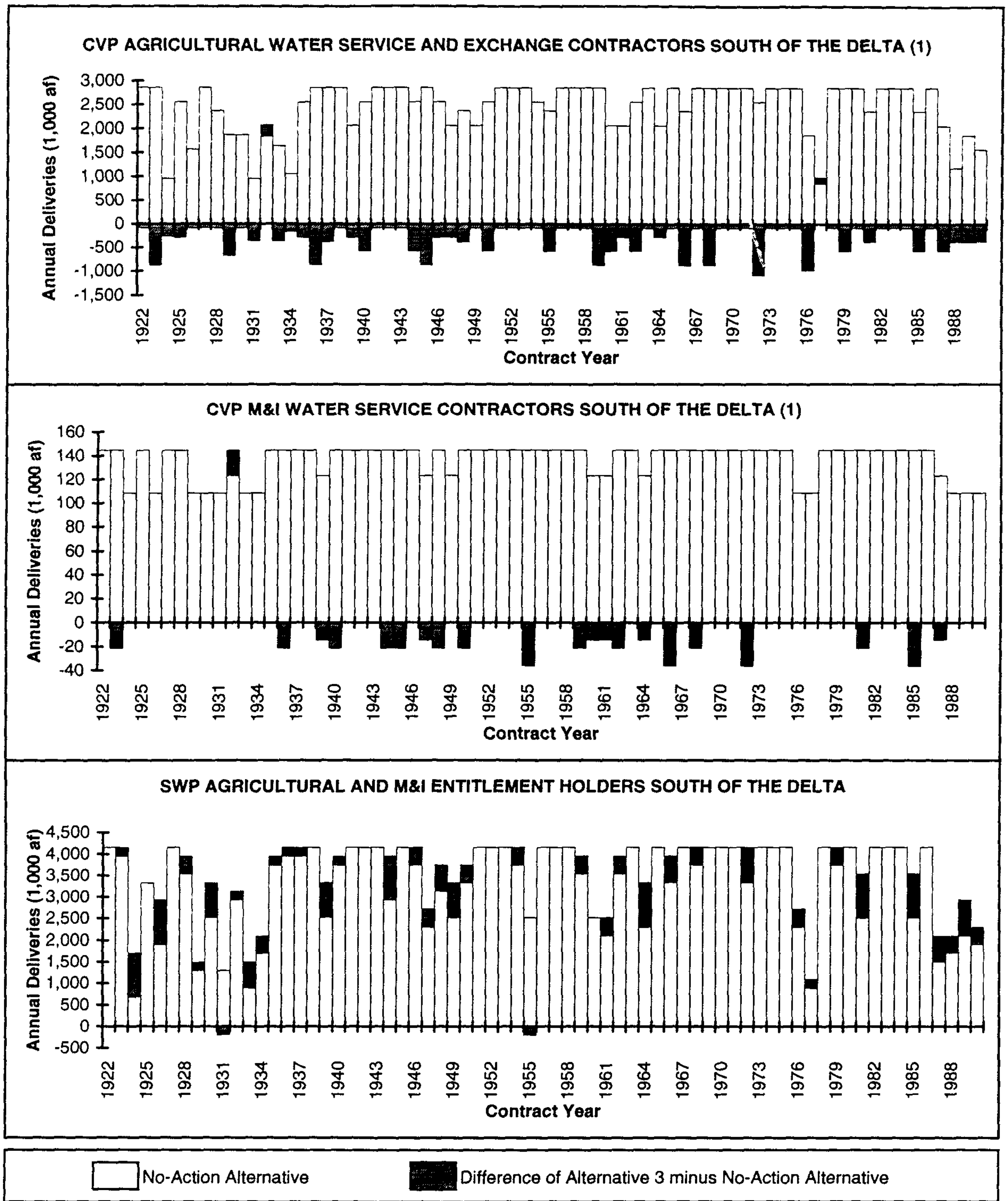
CVP Water Deliveries South of the Delta. Deliveries to CVP San Joaquin Exchange Contractors would be similar to those described in the No-Action Alternative. Figure III-22 shows the comparison of frequency distributions for CVP agricultural and M&I water service contractor deliveries as compared to the No-Action Alternative. The figure shows that water service contractors receive greater deliveries than in Alternative 1, due to the export of acquired water after it reaches the Delta. The difference in simulated annual deliveries as compared to the No-Action Alternative is shown in Figure III-59.

CVP Water Deliveries To Refuges. Alternative 3 includes annual deliveries of Level 4 water supplies to refuges as shown in Figure III-24, in comparison to the No-Action Alternative.



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-58
SIMULATED ALTERNATIVE 3 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-59
SIMULATED ALTERNATIVE 3 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990

ALTERNATIVE 3 IMPACTS ON SWP OPERATIONS AND DELIVERIES

This section provides a comparison of Alternative 3 and No-Action Alternative SWP reservoir operations, resulting river flows, and water deliveries to SWP contractors. A comparison of deliveries to SWP contractors in the Alternative 3 simulation, as compared to deliveries in the No-Action Alternative simulation, is provided in Table III-16.

TABLE III-16
COMPARISON OF SWP DELIVERIES IN THE ALTERNATIVE 3 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual SWP Deliveries (1,000 acre-feet)		Average Annual Change in SWP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 3	
1922 - 1990	Simulation Period	3,330	3,600	+270
1928 - 1934	Dry Period	2,050	2,400	+350
1967 - 1971	Wet Period	4,140	4,200	+60

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

SWP Operations

Alternative 3 SWP operations and deliveries are affected by the ability to export acquired water through Banks Pumping Plant, when it reaches the Delta. The large capacity of Banks Pumping Plant and the SWP's flexibility to reduce Lake Oroville releases, allow the SWP to adapt operations to take advantage of the acquired water as it becomes available in the Delta.

Lake Oroville and Feather River Operations. The slight differences in Lake Oroville end-of-water year storage are shown in a comparison of frequency distributions for Alternative 3 and the No-Action Alternative, in Figure III-2. Average monthly flows in the Feather River at Nicolaus are similar to the No-Action Alternative as shown in Figure III-25.

Delta Operations. SWP Banks Pumping Plant exports increase in Alternative 3 by 270,000 acre-feet per year as compared to the No-Action Alternative. Figure III-18 shows a comparison of the frequency distributions for annual SWP exports, and also shows the change in average monthly Banks Pumping Plant exports.

San Luis Reservoir Operations. The Alternative 3 SWP average monthly storage in San Luis Reservoir is similar to the No-Action Alternative as shown in Figure III-18.

SWP Entitlement Water Deliveries

Alternative 3 average annual deliveries to SWP agricultural and M&I entitlement holders south of the Delta are 270,000 acre-feet per year greater than in the No-Action Alternative because acquired water can be exported through Banks Pumping Plant after it reaches the Delta. Figure III-22 shows a comparison of the SWP delivery frequency distributions for Alternative 3 and the No-Action Alternative. Figure III-59 shows the difference in annual SWP deliveries.

ALTERNATIVE 4

DESCRIPTION OF ALTERNATIVE

The water management provisions in Alternative 4 include all of the provisions in Alternative 3, plus additional (b)(2) Water Management actions in the Delta, and the acquisition of water from willing sellers for increased instream flow and Delta outflow. Under Alternative 4, the (b)(2) Water Management to meet target flows on CVP-controlled streams and towards 1995 Water Quality Control Plan requirements would be similar to the (b)(2) Water Management in Alternative 3. The delivery of firm Level 2 water supplies to wildlife refuges, and the revised instream fishery flow releases on the Trinity River would the same as described under Alternative 1.

Alternative 4 includes the acquisition of water from willing sellers for the delivery of Level 4 water supplies to wildlife refuges, as described under Alternative 2, and the acquisition of water for increasing stream flows toward flow targets identified in Attachment G-4 of the Draft PEIS, as described under Alternative 3. Water would be acquired to improve instream flow conditions on the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Yuba rivers. Under Alternative 4, the acquired would be used to increase both instream flow and Delta outflow, and would therefore not be available for export by the CVP or SWP.

Similar to Alternative 1, the CVP would be operated under Alternative 3 in an attempt to increase end-of-month storage in September in Shasta and Folsom lakes to provide increased river releases during the fall in the Sacramento and American rivers. As compared to the No-Action Alternative, increased reservoir releases would also be made from Whiskeytown Lake to increase Clear Creek minimum flows year round, and from New Melones Reservoir to provide higher flows on the Stanislaus River to attempt to meet target flows. Increased Clair Engle Lake releases, to meet increased Trinity River flow releases in this alternative, would result in a decrease in spring and early summer diversions to the Sacramento River. Also similar to Alternative 1, Alternative 4 includes implementation of the habitat restoration actions.

PEIS (b)(2) WATER MANAGEMENT FOR ALTERNATIVE 4

Alternative 4 includes the use of (b)(2) water to attempt to meet fishery objectives in the Delta, in addition to the (b)(2) actions on CVP-controlled streams that are included in Alternative 3. A simplified version of (b)(2) Water Management was developed that integrated nine proposed Delta (b)(2) water actions into Alternative 4. It is recognized that this simplified analysis is for the purposes of the Draft PEIS only, and that the formal WMP process, involving Reclamation and the Service, will provide detailed evaluation of the use of (b)(2) water for incorporation into CVP operating prescriptions for Reclamation's Operations and Criteria Plan.

In contrast to the proposed preliminary February 1996 Delta (b)(2) actions that were evaluated in Supplemental Analysis 1a, the Delta (b)(2) actions evaluated in Alternative 4 were developed based on preliminary information released by the Service in October 1996, which is presented in Attachment G-5 of the Draft PEIS. The Delta (b)(2) actions outlined in this attachment are a refinement of the preliminary potential actions originally proposed in February 1996, and evaluated in Supplemental Analysis 1a. The assumptions and process to develop a (b)(2) Water Management strategy for Alternative 4 are discussed in Attachment G-2 of the Draft PEIS.

The nine Delta (b)(2) actions in Alternative 4 are listed below according to priority**, as developed by the Service**. The highest priority action is assigned the number 1.

1. Limit CVP/SWP April and May exports to a percent of San Joaquin River at Vernalis flow based on water year type.

2. Head of Old River barrier in place April through May.

3. Increase level of May and June X2 requirement to 1962 level of development.

4. Provide 13,000 cfs at "I" Street Bridge and 9,000 cfs at Knights Landing on Sacramento River in May.

5. Ramp total CVP/SWP export/inflow ratio levels April 1 to April 15 and May 15 through May 31.

6. Close Delta Cross Channel Gates November 1 through January 31

7. Limit CVP/SWP exports to 35 percent of Delta inflow in July.

8. Establish conditions for a late fall run smolt survival experiment.

9. Limit CVP/SWP total exports to 35 percent of Delta inflow in November through January.

The potential impacts of all nine Delta (b)(2) actions could not be assessed in the model simulations conducted for the Draft PEIS. The simulations were programmatic in nature and did not have the capability to assess the specific changes that might occur as a result of the implementation of actions 2, 5, and 8. Although the models did not allow quantification of the potential impacts, some general assessments were made where possible.

WATER ACQUISITION IN ALTERNATIVE 4

Water acquisition quantities from willing sellers and the use of water in an attempt to meet instream flow targets in Alternative 4 would be the same as described under Alternative 3. Under Alternative 4, the difference is that water would be acquired to increase Delta outflow as well as to improve instream flows; therefore, the acquired water could not be exported by the projects as in Alternative 3. Water would be acquired for increased instream flows on the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Yuba rivers. Water would also be acquired for delivery of Level 4 water supplies to wildlife refuges, in the same manner as described under Alternative 2. Results from Alternative 4 acquisition analyses are shown on figures referenced in the description of impacts associated with Alternative 3.

ALTERNATIVE 4 IMPACTS ON CVP OPERATIONS AND DELIVERIES

Alternative 4 CVP operations and water deliveries are affected by the integrated use of (b)(2) water for instream and Delta objectives, Level 2 refuge deliveries, and increased Trinity River instream flow releases. The Delta (b)(2) actions listed above would require additional reservoir releases primarily in May and June, and would further limit the amount of water that could be exported through Tracy Pumping Plant during the pulse flow period of April 15 to May 15, and during periods with an export/inflow ratio target of 35 percent.

Under Alternative 4, deliveries to CVP water service contractors would not be increased as a result of the management of acquired water. The increased flows that would result from the release of acquired water would flow through the Delta and contribute directly to increasing Delta outflow. Therefore, the acquired water could not be exported by the CVP. However, the CVP would receive some incidental benefit toward meeting Delta water quality and outflow requirements, since the increase in Delta outflow resulting from the release of acquired water would improve monthly antecedent water quality conditions in the Delta. The reduction in water deliveries to CVP contractors in Alternative 4, as compared to the No-Action Alternative, is summarized in Table III-17. A discussion of CVP operations and deliveries is provided below.

CVP Operations

In Alternative 4, CVP operations in the Trinity, Shasta, Sacramento River, and American River divisions would be similar to Alternative 1. There are minor changes in upstream CVP reservoir operations due to changes in Delta operations, but the operation of the upstream reservoirs is dominated by the need to make releases for water rights, upstream (b)(2) water objectives, and biological opinion requirements.

TABLE III-17
COMPARISON OF CVP DELIVERIES IN THE ALTERNATIVE 4 AND NO-ACTION ALTERNATIVE SIMULATIONS

Contract Years	Type of Period	Simulated Average Annual CVP Deliveries (1,000 acre-feet)		Average Annual Change in CVP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 4	
1922 - 1990	Simulation Period	5,770	5,150	-620
1928 - 1934	Dry Period	4,560	3,970	-590
1967 - 1971	Wet Period	6,310	5,840	-470

NOTES:
(1) CVP deliveries include deliveries to agricultural and M&I water service contractors, Sacramento River water rights contractors, other water rights contractors, San Joaquin Exchange Contractors. CVP deliveries do not include refuge water supplies.
(2) Alternative 4 assumes purchase of up to 130,000 acre-feet of water per year for level 4 refuges from the Sacramento River Water Rights and San Joaquin River Exchange Contractors.

Friant Division operations would be similar to the No-Action Alternative. CVP operations in the Eastside Division would be similar to Alternative 3 because of the acquisition of water from willing sellers on the Stanislaus, Tuolumne, and Merced rivers. Operations in the Delta and West San Joaquin divisions would be affected due to higher Delta inflows from acquired water and the additional Delta (b)(2) actions. The operations of these divisions are discussed below.

Delta Division. As a result of upstream water acquisitions, simulated Delta inflows increase by about 400,000 acre-feet per year in Alternative 4 as compared to the No-Action Alternative. In Alternative 4, this additional inflow may not be exported by the CVP because it is acquired for instream and Delta outflow purposes. Tracy Pumping Plant exports decrease by about 300,000 acre-feet per year as compared to the No-Action Alternative, and decrease by about 40,000 acre-feet per year as compared to Alternative 1. Figure III-18 shows the frequency distributions for simulated annual Tracy Pumping Plant exports for Alternative 4 and the No-Action Alternative.

The Delta (b)(2) actions in Alternative 4 limit Tracy Pumping Plant exports primarily during April 15 through May 15, and require that additional water be released from upstream reservoirs in February through June for additional X2 requirements. Figure III-17 shows the decrease in average monthly Tracy Pumping Plant exports as compared to the No-Action Alternative.

Simulated Delta outflow increases by about 780,000 acre-feet per year as compared to the No-Action Alternative. Average monthly Delta outflows in the No-Action Alternative and Alternative 4 simulations are presented in Figure III-19. The primary increase in Delta outflow occurs in April and May due to the increase in Delta inflows from acquired water upstream releases, the reductions in Tracy and Banks Pumping Plant exports, and additional (b)(2) water releases for the increased number of X2 days at Chipps Island in May and June.

The Delta (b)(2) actions in Alternative 4 affect Delta inflows, outflows, and the ability to export water through Tracy Pumping Plant. Some of the Delta (b)(2) actions could not be implemented in all years over the 69-year simulation period due to existing operational constraints and criteria. These constraints include the need to meet water rights requirements, maintain SWP deliveries at the No-Action Alternative level, maintain Reclamation's ability to provide adequate storage in Shasta Lake to meet Winter Run Biological Opinion temperature control requirements, and the limit on the reduction in CVP deliveries due to use of (b)(2) water to no more than 800,000 acre-feet per year on an average annual basis.

Under Alternative 4, the highest priority Delta (b)(2) action, which limits CVP/SWP exports in April and May, would be met in all years over the 69-year simulation period. Action 3, the increase in the number of X2 days at Chipps Island in May and June, would also be met in all years. Action 4, which consists of increasing the flows at Knights Landing and at the "I" Street Bridge on the Sacramento River in May, was met in 22 and 59 percent of May in the 69-year simulation period. Implementation of Action 6, the closure of the Cross Channel Gates in November 1 through January 31, would be limited to wet and above normal water year types. Action 7, the limitation on CVP/SWP exports to 35 percent of Delta inflow in July, would be met in 56 percent of July in the 69-year simulation period. Action 9, which limits CVP/SWP exports to 35 percent of Delta inflow in November through January, would be met in 32, 38, and 57 percent of November, December, and January, respectively, over the simulation period.

The impacts of Delta (b)(2) actions 2, 5, and 8 were not quantitatively evaluated in the model simulations conducted for Alternative 4, but a general assessment of potential impacts may be made for actions 2 and 5. Action 8 is not assessed due to its experimental nature, and the need to establish experiment criteria and conditions. For action 2, the placement of the barrier at the head of Old River in April and May, it is generally assumed that the barrier would have minimal impact on CVP Delta operations. Action 5, the ramping of total CVP/SWP export/inflow ratio levels April 1 to April 15 and May 15 to May 31, would further reduce project exports during the ramping period. Estimates of the export/inflow ratio for the pulse period show ratios in the range of 5 to 15 percent, as compared to the 35 percent ratio that is in effect preceding and following the pulse period.

West San Joaquin Division. Operations of the CVP portion of San Luis Reservoir are similar to Alternative 1. As shown in Figure III-18, Alternative 4 simulated average monthly storage is greater in March than in the No-Action Alternative. This is caused by higher fall exports due to increased upstream CVP reservoir releases for (b)(2) Water Management. CVP San Luis Reservoir storage is reduced earlier in the spring due to reduced Tracy Pumping Plant exports in April and May.

CVP Contract Water Deliveries

In Alternative 4, upstream acquired water would not be exported through Tracy Pumping Plant when it reaches the Delta. Therefore the major effect on CVP deliveries is due to the additional (b)(2) actions in the Delta. These actions have minor effects on CVP deliveries north of the Delta, and primarily affect deliveries south of the Delta dependent on Tracy Pumping Plant exports. The resulting changes in CVP deliveries are discussed below.

CVP Water Deliveries North of the Delta. Deliveries to CVP Sacramento River Water Rights Contractors would be similar to those described in the No-Action Alternative. Deliveries to CVP agricultural and M&I water service contractors north of the Delta would be similar to those in Alternative 1. Figure III-60 shows a comparison of the Alternative 4 and No-Action Alternative deliveries.

CVP Water Deliveries Eastside Division. The deliveries to CVP agricultural water service contractors on the Stanislaus River in Alternative 4 would be similar to those described in Alternative 3.

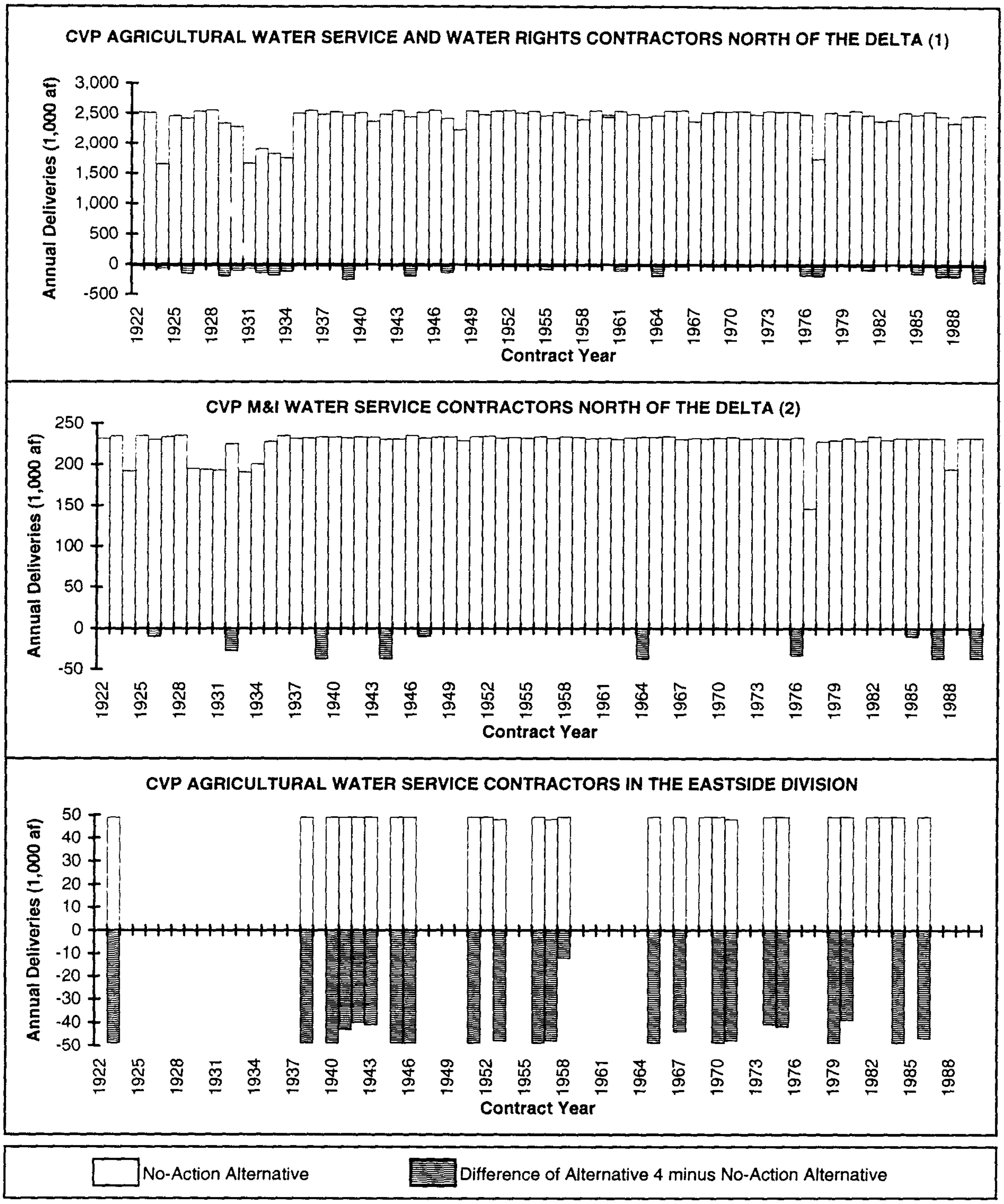
CVP Water Deliveries South of the Delta. Deliveries to CVP San Joaquin Exchange Contractors would be similar to those described in the No-Action Alternative. Figure III-22 shows the comparison of frequency distributions for CVP agricultural and M&I water service contractor deliveries as compared to the No-Action Alternative. The figure shows that CVP water service contractors south of the Delta receive lower deliveries than in the No-Action Alternative, and slightly lower than in Alternative 1. The limitations on Tracy Pumping Plant April and May exports directly affect the amount of water that can be delivered to southern water service contractors. The difference in simulated annual deliveries as compared to the No-Action Alternative is shown in Figure III-61.

CVP Water Deliveries To Refuges. Alternative 4 includes annual deliveries of Level 4 water supplies to refuges as shown in Figure III-24, in comparison to the No-Action Alternative.

ALTERNATIVE 4 IMPACTS ON SWP OPERATIONS AND DELIVERIES

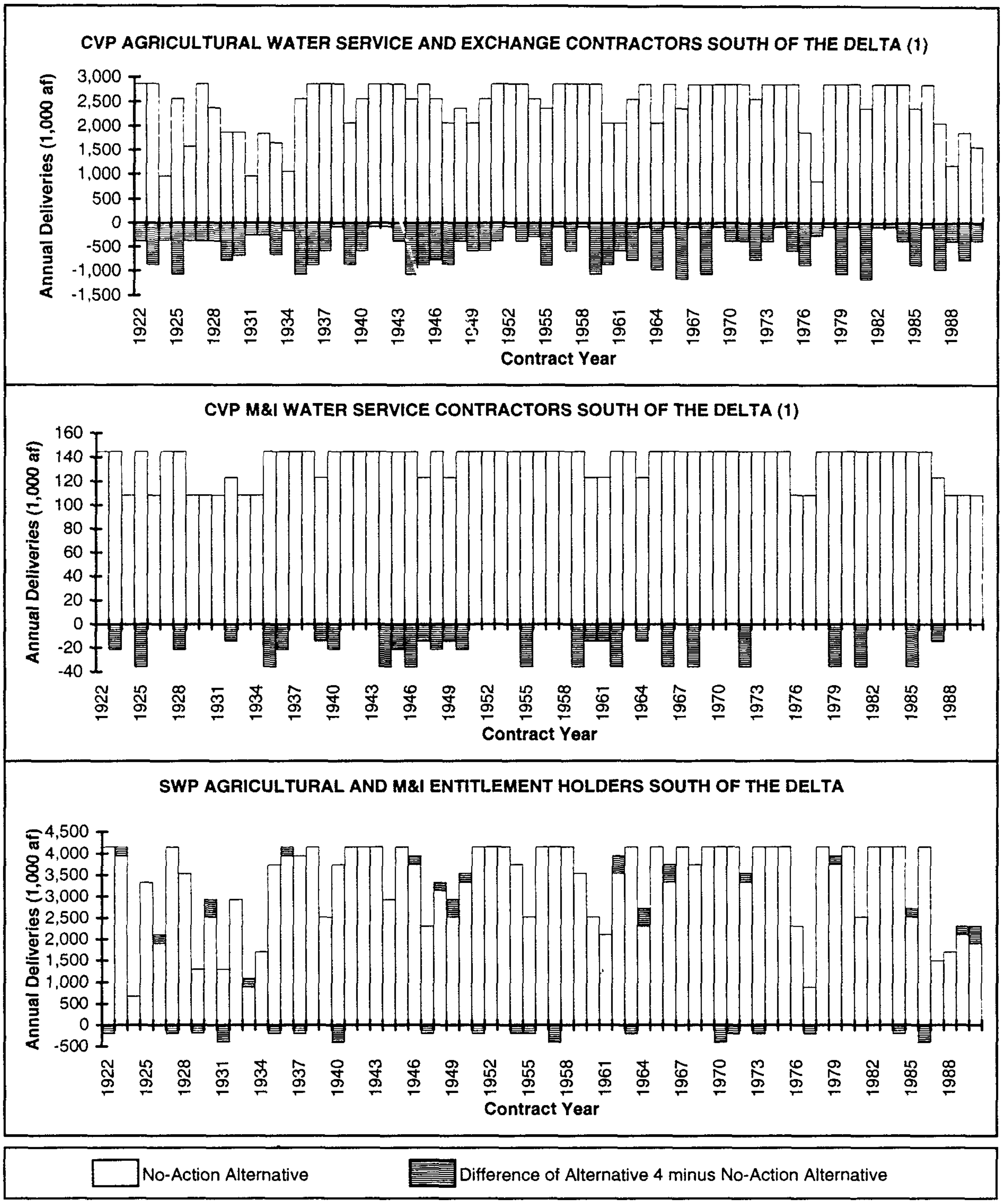
For the purposes of the PEIS (b)(2) Water Management analysis, it was assumed that the SWP would cooperate with implementation of the Delta (b)(2) actions by reducing exports during specified periods and making releases to contribute to additional levels of Delta protection. It was also assumed that any negative impacts to the SWP, due to this cooperation in Alternative 4, would not exceed the benefits shown in Alternative 1. Therefore, there would be no net impact to average annual SWP deliveries as compared to the No-Action Alternative.

This section provides a comparison of Alternative 4 and No-Action Alternative SWP reservoir operations, resulting river flows, and water deliveries to SWP contractors. A comparison of deliveries to SWP contractors in the Alternative 4 simulation, as compared to deliveries in the No-Action Alternative simulation, is provided in Table III-18.



NOTES: (1) Includes Sacramento River and American River Divisions.
(2) Includes Sacramento River and American River Divisions plus Contra Costa exports.

FIGURE III-60
SIMULATED ALTERNATIVE 4 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990



NOTE: (1) Includes Delta (DMC only), West San Joaquin, and San Felipe Divisions.

FIGURE III-61
SIMULATED ALTERNATIVE 4 DELIVERIES AS COMPARED TO THE NO-ACTION ALTERNATIVE 1922-1990

**TABLE III-18
COMPARISON OF SWP DELIVERIES IN THE
ALTERNATIVE 4 AND NO-ACTION ALTERNATIVE SIMULATIONS**

Contract Years	Type of Period	Simulated Average Annual SWP Deliveries (1,000 acre-feet)		Average Annual Change in SWP Deliveries (1,000 acre-feet)
		No-Action Alternative	Alternative 4	
1922 - 1990	Simulation Period	3,330	3,310	-20
1928 - 1934	Dry Period	2,050	2,050	0
1967 - 1971	Wet Period	4,140	3,990	-150

NOTES:
(1) SWP deliveries include deliveries south of the Delta to entitlement holders. SWP deliveries do not include refuge water supplies.

CHAPTER IV

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Chapter IV

BIBLIOGRAPHY

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CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT TECHNICAL APPENDIX

Soils and Geology

September 1997

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LIST OF ABBREVIATIONS AND ACRONYMS

CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DWR	California Department of Water Resources
PEIS	Programmatic Environmental Impact Statement
PM_{10}	particulate matter of 10 microns or less in diameter
SCS	U.S. Department of Agriculture Soil Conservation Service
SJVAB	San Joaquin Valley Air Basin
SVAB	Sacramento Valley Air Basin
SWP	State Water Project
TSP	total suspended particulates
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Draft Programmatic Environmental Impact Statement (PEIS) summarizes the evaluation of the direct and indirect impacts of implementing a wide range of actions identified in the Central Valley Project Improvement Act (CVPIA). Details of the information used in the definition of the affected environment and analysis of the environmental consequences are presented in the technical appendices of the Draft PEIS.

This technical appendix presents a summary of soils and geology background information that was used during the PEIS preparation, and the results of the impact analyses for conditions that occurred throughout the study area, shown in Figure I-1.

The soils and geology analysis was primarily based upon:

(1) changes in agricultural land use because of potential for erosion of disturbed agricultural soils; and

(2) changes in stream flows because of potential for erosion along river channels. Information from the Agricultural Economics and Land Use and the Surface Water and Facilities Operations technical appendices was used in the soils and geology analyses.

The assumptions and results of the analyses for Alternatives 1, 2, 3, and 4 are presented in this technical appendix and summarized in the Draft PEIS. The assumptions and results of the analyses for Supplemental Analyses 1a through 1i, 2a through 2d, 3a, and 4a are summarized only in the Draft PEIS. The assumptions related to the soils and geology analyses for Alternatives 1, 2, 3, and 4 are presented in Table I-1. The results of the analyses are presented in Table I-2.

TABLE I-1

SUMMARY OF ASSUMPTIONS FOR SOILS AND GEOLOGY ANALYSES

Alternative or Supplemental Analysis	Assumption
No-Action Alternative	Municipal and agricultural land uses as described in California Department of Water Resources Bulletin 160-93.
1	Changes in cultivated acreage is the primary factor that would affect soils and geology.
2	Changes in cultivated acreage is the primary factor that would affect soils and geology.
3	Changes in cultivated acreage is the primary factor that would affect soils and geology.
4	Changes in cultivated acreage is the primary factor that would affect soils and geology.

FIGURE I-1
STUDY AREA

C-080310

C-080312

TABLE I-2

SUMMARY OF IMPACT ASSESSMENT OF SOILS AND GEOLOGY

Affected Factors	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
		Change from No-Action Alternative			
Erosion Potential	Similar to existing conditions	Similar to No-Action Alternative due to use of final cultivation plans for fallowed fields and retired lands; and due to habitat restoration along stream channels	Similar to Alternative 1	Similar to Alternative 1	Similar to Alternative 1

C-080311

C-080313

CHAPTER II

AFFECTED ENVIRONMENT

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Chapter II

AFFECTED ENVIRONMENT

INTRODUCTION

This technical appendix describes the soils and geology resources that may be affected by the implementation of the CVPIA. This technical appendix describes primary soil types within the Central Valley. Several soil associations (geographic areas where certain soils regularly occur together) may be present in a particular physiographic region. For this PEIS, soils of the Central Valley are examined on the basis of their physiographic location in the valley. Physiographic regions include valley land, valley basin land, terrace land, and upland. Within a region, several soil groups may have distinctive characteristics that separate them from other soils in the region. These soil groups are discussed separately for soils on the valley floor. Six of the 11 geologic provinces in California are discussed in this technical appendix, with particular attention to the Central Valley.

DATA SOURCES

The U.S. Department of Agriculture Soil Conservation Service (SCS) has published more than 150 County and area Soil Surveys in California since the early 1900s. Work on soil surveys is continuous in each county, and individual county reports are updated periodically. Soil surveys were collected for counties in the Sacramento River Basin, San Joaquin River Basin and the Tulare Lake Region.

Geology information for this report was collected from the U.S. Geological Survey (USGS), California Division of Mines and Geology, and the California Division of Oil and Gas. Other private publications on state geology were also reviewed.

RECENT CONDITIONS

In the Central Valley, soils are divided into four physiographic regions, as summarized in Table II-1. Valley land and valley basin land soils occupy most of the Central Valley floor. Valley land soils consist of deep alluvial and aeolian soils that make up some of the best agricultural land in the state. Valley basin lands consist of organic soils of the Sacramento-San Joaquin Delta, poorly drained soils, and saline and alkali soils in the valley trough and on the basin rims.

TABLE II-1

SOILS SUMMARY TABLE

Physiographic Region	Location	Texture	Non-Irrigated Crops	Irrigated Crops	Additional Features
Valley Land					
Alluvial Soils	Alluvial fans and low terraces in the Sacramento and San Joaquin valleys	Sandy loam - loam		Alfalfa, vegetables, fruits, sugar beets, cotton	
Aeolian Soils	Portions of Stanislaus, Merced, and Fresno counties	Sands - loamy sand		Fruits, alfalfa	Prone to wind erosion; soil deficient in plant nutrients
Valley Basin					
Organic Soils	Sacramento-San Joaquin Delta	Peat, organic		Grains, sugar beets, alfalfa, fruits, vegetables, nuts	Peat soils prone to subsidence
Imperfectly Drained Soils	Sacramento-San Joaquin Valley Trough	Clays	Pasture	Pasture, rice, cotton	High water table
Saline/Alkaline Soils	West side of San Joaquin Valley	Clay loam - clay	Pasture	Grains, rice, cotton	Leaching required to remove excess salts
Terrace Land					
Brown, Neutral Soils	West side Sacramento Valley and Southeast side San Joaquin Valley	Loam Clay	Pasture	Pasture	
Red-Iron Hard Pan Soils	East side Sacramento and San Joaquin valleys	Sandy loam - loam hardpan	Alfalfa, grains, pasture	Fruits	Hardpan layer present
Upland Soils					
Shallow Depth to Bedrock	Foothills surrounding Central Valley	Loam - clay loams	Pasture		Tilled soils prone to erosion
Moderate Depth to Bedrock	East side Merced and Stanislaus counties	Sandy loam - clay loam	Pasture		
Deep Depth to Bedrock	Higher elevations of the Sierra Nevada, Klamath Mountains, and Coast Range	Loam - clay loams	Timberland		Granitic soils on steep slopes highly susceptible to erosion

SOURCE:
University of California, 1980.

Areas above the Central Valley floor consist of terrace and upland soils. Overall, these soils are not as productive as the valley land and valley basin land soils. Without irrigation, these soils are primarily used for grazing and timberland; with irrigation, additional crops can be grown.

VALLEY LAND

Valley land soils are generally found on flat to gently sloping surfaces such as on alluvial fans. These well-drained soils include some of the best all-purpose agricultural soils in the state. Both alluvial- and aeolian-deposited soils are present in the Central Valley.

Alluvial Soils

Alluvial-deposited valley land soils include the calcic brown, noncalcic brown, and gray desert alluvial soils. Figure II-1 shows the distribution of all Central Valley alluvial soils.

Calcic brown and noncalcic brown alluvial soils are found in the Central Valley on deep alluvial fans and flood plains occurring in intermediate rainfall (10 to 20 inches annually). These two soils tend to be brown to light brown with a loam texture that forms soft clods. Calcic brown soil is calcareous; noncalcic soil is usually neutral or slightly acid. These soils are highly valued for irrigated crops such as alfalfa, apricots, carrots, corn, lettuce, peaches, potatoes, sugar beets, and walnuts. Where the climate is suitable, avocados, citrus fruits, cotton, and grapes can be grown. These soils are found in the Sacramento Valley and the northern and central San Joaquin Valley as shown in Figure II-1.

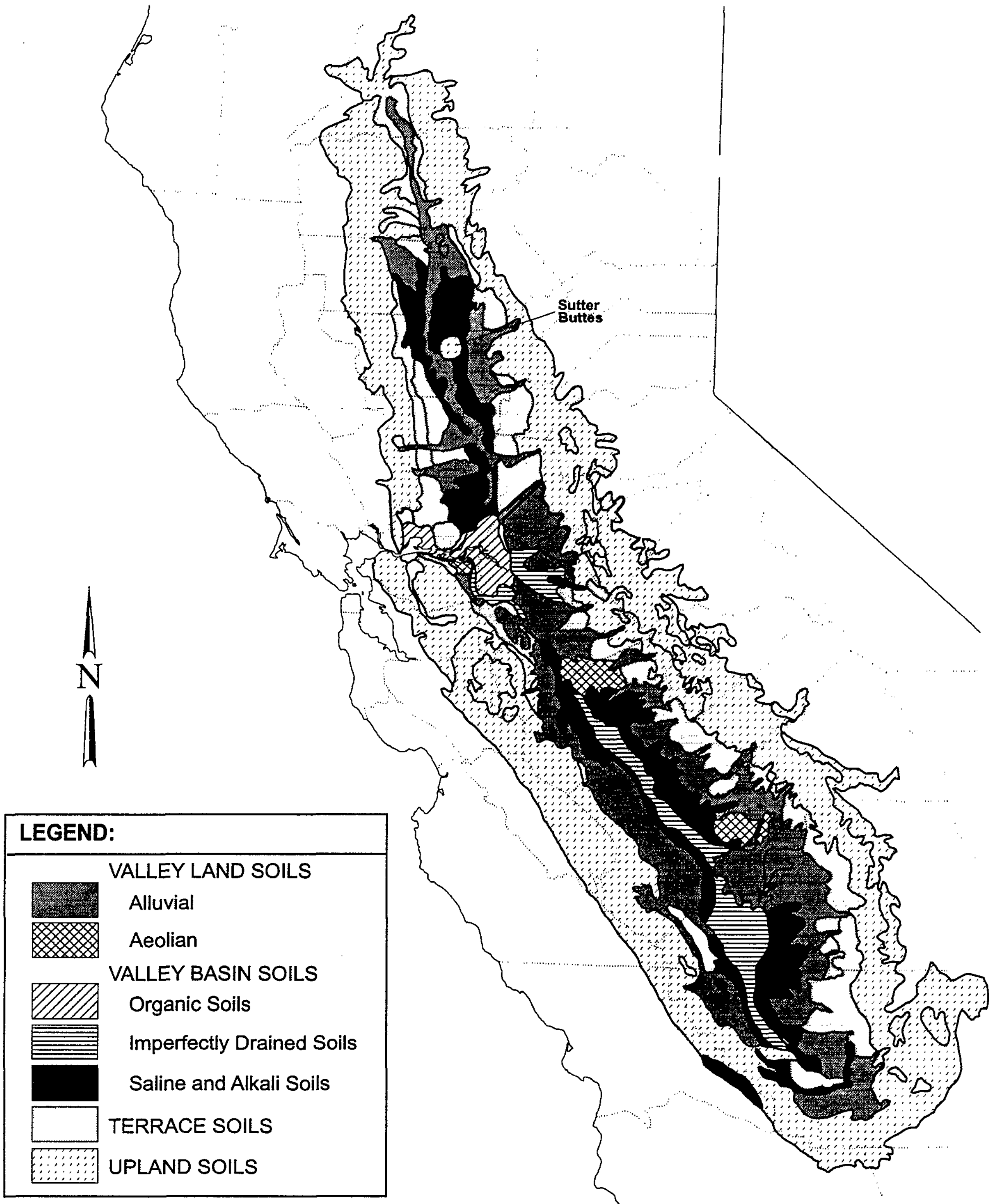
Gray desert alluvial soil is found on alluvial fan and flood plains of low rainfall (4 to 7 inches annually). This soil appears in the western San Joaquin Valley as light-colored calcareous soil low in organic matter. These soils are too dry to produce crops without irrigation. When irrigated, these soils are valued for alfalfa, cotton, and flax.

Aeolian Soils

Aeolian-deposited and wind-modified soils of the Central Valley are noncalcic brown sand soils. These soils primarily are found in the east side of the San Joaquin Valley, as shown in Figure II-1. A small pocket also can be found in the western Delta. Soils in this area receive 8 to 13 inches of rainfall annually. These soils are light brown, sandy, and neutral to acid. With irrigation, these soils may produce many crops including grapes, sweet potatoes, watermelons, and alfalfa. These soils are prone to wind erosion, have low water-holding capacity, and are somewhat deficient in plant nutrients.

VALLEY BASIN LAND

Soils in this topographic division occupy the lowest parts of the Central Valley. The three general groups within this division are organic soils, imperfectly drained soils, and saline/alkali soils.



SOURCE: University of California, 1980

FIGURE II-1

SOIL TYPES IN THE CENTRAL VALLEY

Organic Soils

Organic soils are dark because of their high organic content, which ranges from 10 to 80 percent. The soils are found in the Delta, as shown in Figure II-1. They are generally poorly drained, highly organic, and acidic. Cultivated areas are primarily irrigated with water diverted from the Delta and groundwater with drainage flows returned to the Delta. Currently about 1,800 agricultural diversions divert water from the Delta for irrigating corn, grains, sugar beets, alfalfa, tomatoes, asparagus, fruit, safflower, and nuts.

Peat soils of the Delta were formed under water-logged anaerobic conditions in which decayed plant material accumulated faster than it decomposed. This process continued for thousands of years before Delta lands were reclaimed by an extensive series of levees in the late nineteenth and early twentieth centuries. At present, some areas of the Delta have peat layers more than 50 feet thick.

Peat soils in the Delta are disappearing at a rate of 1 to 3 inches per year for several reasons. First, reclaiming the land stopped the accumulation process. Second, exposing peat soils to air causes the soils to convert organic carbon solids to carbon dioxide and aqueous carbon. During World War II (1939-1945), it was common practice on some Delta islands to burn peat soils between crops to improve conditions for potatoes and sugar beets, which were in high demand. During controlled burns in the peat fields, up to 3 inches of soil could burn, resulting in 0.08 to 0.13 inch per year of subsidence. Peat soils are susceptible to wind erosion, which causes soil loss and possible air quality problems. Elevation measurements made from 1922 to 1981 indicate that agricultural practices, regardless of crop type, tend to cause 1 to 3 inches of subsidence per year (USGS, 1991).

Groundwater and oil and gas extraction does not appear to contribute to the subsidence in the Delta. Extensometer data indicate 0.005 feet of temporary subsidence from groundwater pumping in the summer months, but the aquifer material rebounds during the winter. Gas has been extracted in and around the Delta since the 1930s. Natural gas is extracted from about 4,500 feet below the land surface. Any subsidence caused by gas extraction depends on the compressibility and permeability of the gas reservoir and the surrounding rocks and is not related to events at the ground surface.

Imperfectly Drained Soils

This group of soils generally contains dark clays and has a high water table or is subject to overflow. These soils are found in the troughs of the Sacramento and San Joaquin valleys, as shown in Figure II-1. Some San Joaquin Valley soils contain alkali. Dry land farming on these lands produce wheat and barley. Native pasture and irrigated pasture also grow well on this soil. When irrigated, these soils are used extensively for rice in the Sacramento Valley. These soils tend to be gray to dark gray with high clay content that forms clods and may be neutral to slightly calcareous.

Saline/Alkali Soils

These soils are characterized by excess salts (saline), excess sodium (sodic) or both (saline-sodic). In many of the older soil surveys, salinity and sodicity were jointly referred to as alkaline. A distinction was sometimes made since the saline soil many times formed a white crust on the surface and was called "white alkali" and the soils with excess sodic appeared to be "black", thus black alkali. All are fairly common throughout the San Joaquin Valley (Figure II-1). In uncultivated areas, saline soils are used for saltgrass pasture and native range. Some of these soils support seasonal salt marshes. In areas of intermediate to low rainfall, the soils have excess sodium as well as salt.

Many of these soils are irrigated with Central Valley Project or State Water Project (SWP) surface waters or with slight to moderately saline groundwater. In addition, salts are added through application of fertilizers or other additives needed for cropping. The saline soils form a crust on the top of the soils, change the chemical characteristics of the soils in the root zone, and reduce the capability of the soil to transfer applied moisture to the roots. To minimize salinity problems, irrigators apply water to the soil before planting seed or plants to leach the salts from the root zone. Leaching is complicated by poor drainage, low permeability, and high sodium content. Leaching increases salinity in the groundwater aquifers which further exacerbates the salinity problem as the more saline groundwater is used for irrigation. Because of the increase in groundwater salinity, the areas with soil salinity problems have increased. This most recently occurred during the 1987 to 1994 drought, when surface water availability was limited and groundwater use increased. Increased use of leaching also increases the salinity in flows from subsurface drains which affects water quality in surface waters that receive the return flows, or the quality of water and sediments in evaporation ponds. The increase in groundwater salinity and the effects on the capability of the land to be used for irrigated crops is further discussed in the Groundwater Technical Appendix.

TERRACE LAND

Terrace land soils are found along the edges of the Central Valley at elevations 5 to 100 feet above the valley floor. Several groups of terrace soils surround the floor of the Central Valley. Two of the more widespread groups are discussed in the following paragraphs. Terrace soils are grouped together and shown in Figure II-1.

Brown Neutral Soils

The first group consists of moderately dense, brownish soils of neutral reaction. These soils are found in areas receiving 10 to 20 inches of rain per year. On the west side of Sacramento Valley, these terrace soils tend to have a loamy texture; the same soils in the southeast San Joaquin Valley tend to clay. This soil group is commonly used for irrigated pasture; however citrus orchards are grown on some of these soils. Following ripping, these soils are suitable for orchard and vineyard development.

Red Iron Pan Soils

A second type of terrace soil has a red-iron hardpan layer and is found along the east side of the Sacramento and San Joaquin valleys. These soils consist of reddish surface soil with a dense silica-iron cemented hardpan, which is generally 1 foot thick. Some of these hardpan soils have considerable amounts of lime. These soils occur in areas receiving 7 to 25 inches of rain per year. Dry farming practices have fair results with hay, grains, and pastures, although following ripping, these soils are well suited for orchards and vineyards. Grapes are a crop in the San Joaquin Valley where irrigation is available.

Upland Soils

Upland soils are found on hilly to mountainous topography and are formed in place through the decomposition and disintegration of the underlying parent material. The more widespread upland soil groups include shallow depth, moderate depth, and deep depth to bedrock. Two upland soil groups, shallow depth and moderate depth, are more common due to their geographic location and elevation. Upland soils are found around the perimeter of the Central Valley as shown in Figure II-1. Soils on the west side have mostly developed on sedimentary rocks while those on the east side typically developed on igneous rocks.

Shallow Depth to Bedrock. This group of upland soils is found in the Sierra Nevada and Coast Range foothills that surround the Central Valley. The soil has a loam-to-clay-loam texture with low organic matter, and some areas have calcareous subsoils. These soils usually have a shallow depth to weathered bedrock, less than 2 feet. These soils are found in areas of low to moderate rainfall that support grasslands used primarily for grazing. Tilled areas are subject to considerable erosion.

Moderate Depth to Bedrock. This group of upland soils are found on hilly to steep upland areas having medium rainfall and can support grasslands. These soils have a sandy-loam-to-clay-loam texture and moderate depth to weathered bedrock, about 2 feet. This slightly acidic soil group is dark and is found in Stanislaus County and Merced County foothills east of the valley floor.

Deep Depth to Bedrock. This group of upland soils is found at the higher elevations in the Sierra Nevada, Klamath Mountains, and Coast Range on hilly to steep topography. These soils are characterized by moderate to strongly acidic reaction, especially in the subsoils, which can extend 3 to 6 feet before reaching bedrock. Bedrock consists of meta-sedimentary and granitic rocks. Soils forming on granitic rocks are composed of decomposed granitic sands. These soils receive 35 to 80 inches of precipitation per year and support extensive forests.

SOIL-RELATED ISSUES OF CONCERN

Wind Erosion

Soil erodibility, local wind erosion climatic factor, soil surface roughness, width of field, and quantity of vegetative cover affect wind erosion of soils. The climatic factor incorporates the moisture of the surface soil. The more moisture in the soil, the less susceptible it is to wind erosion. Some soils, such as aeolian-deposited sands, are more susceptible to wind erosion than alluvial soils. Soil taken out of irrigation and allowed to remain barren with no cover vegetation will have greater losses to wind erosion than the same soils under a good crop and land management program with irrigation. Recent SCS County Soil Surveys include information regarding the wind erodibility of the soil mapping units.

There are several concerns about wind-eroded soils. Wind erosion makes the soil shallower and can remove organic matter and needed plant nutrients. Also, blowing soil particles can damage plants, particularly young plants. Blowing soils can also cause offsite problems such as reduced visibility and increased allergic reaction to dust. Some soils on the west side of the San Joaquin Valley have naturally occurring asbestos. If these soils become airborne, the local population, as well as any nearby surface water facilities, could be affected. Soils prone to wind erosion require a vegetation cover to reduce or eliminate the impacts of blowing soils. Providing water for native plants may allow weeds to grow, potentially providing food and habitat value for wildlife, but also potentially requiring the increased use of pesticides on adjacent farmlands to control weeds, insects, and crop diseases. Also, uncultivated areas covered with cover crops can become fire hazards.

Wind erosion from cultivated and uncultivated soils may result in fine particles remaining airborne for a considerable time. Total suspended particulates (TSP) consist of fine airborne dust that is small enough to remain suspended in the air for a long time. Particulate matter of 10 microns (PM_{10}) or less in diameter is small enough to be inhaled, passed through the respiratory system, and lodged in the lungs with resultant health effects. PM_{10} includes dust, silt-and clay-sized particles, salt spray, metallic and mineral particles, pollen, mist, and acid fumes. Wind erosion of agricultural lands creates significant airborne dust. Individual analyses of PM_{10} levels in the Sacramento Valley Air Basin (SVAB) and the San Joaquin Valley Air Basin (SJVAB) are presented in the Air Quality Technical Appendix.

Water Erosion

There are several types of water-based soil erosion. In order of increasing erodibility they are; sheet, splash, and rill and gully erosion. Some factors that influence the erodibility of soils include land slope, surface texture and structure, infiltration rate, permeability, particle size, and the presence of organic or other cementing materials. Level land erodes less than sloped land because flow velocities are less. Based on this factor alone, terrace and upland soils would be more susceptible to water erosion than soils on the valley floor.

The Universal Soil Loss Equation (USLE) is widely used to predict the severity of erosion from farm fields. Six factors that determine the long-term average annual soil loss for a given location are long-term average rainfall-runoff erosivity factor, soil erodibility index, slope length factor, slope gradient factor, soil cover factor, and an erosion control practice factor. The detailed nature of this estimation prevents extrapolation to a regional level. The SCS Soil surveys provide detailed information on soil erosion by soil mapping units.

Soil Salinity

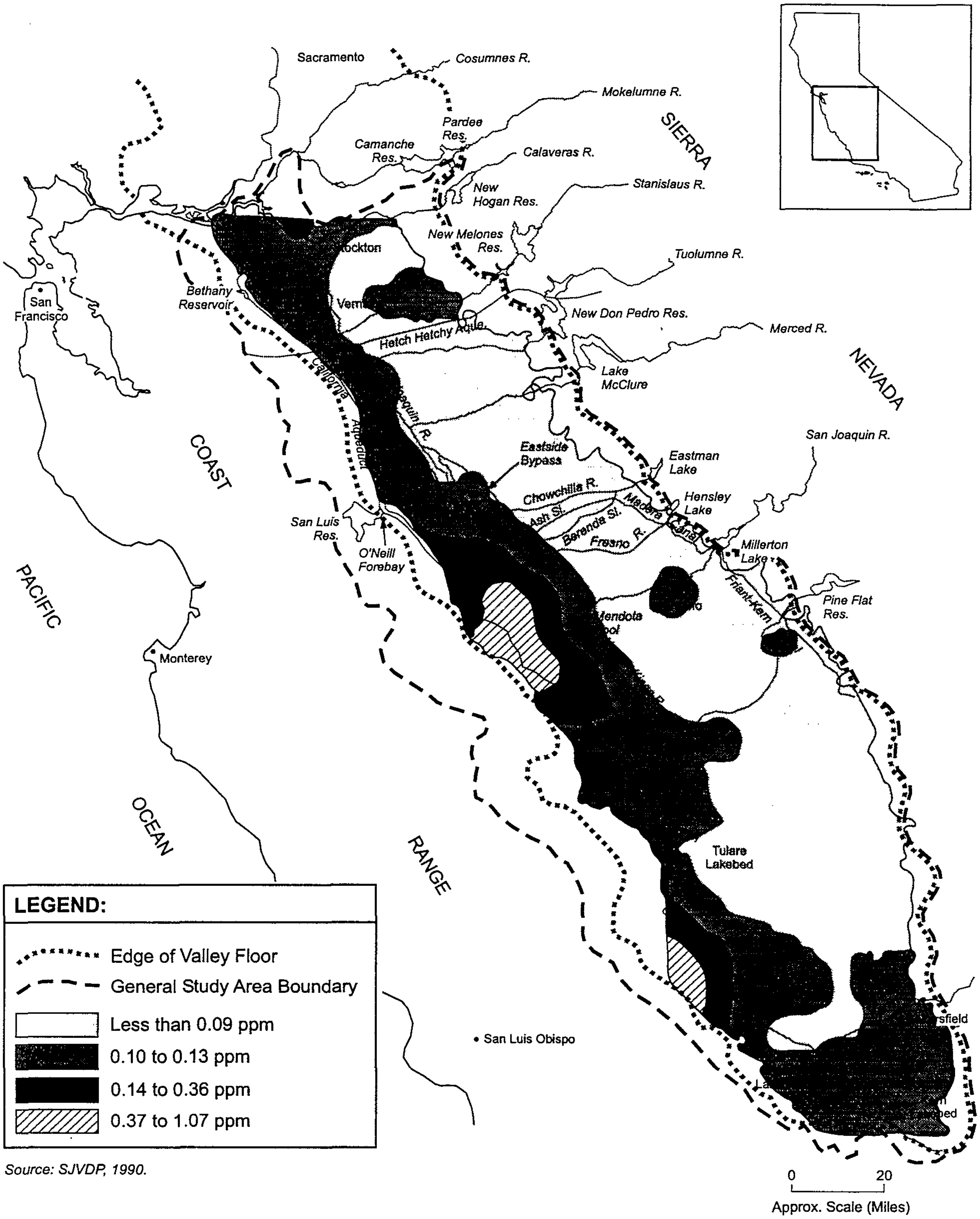
Soil salinity problems occur primarily in the western and southern portions of the San Joaquin Valley. Most soils in this region are derived from marine sediments of the Coast Range, which contain salts and potentially toxic trace elements such as arsenic, boron, molybdenum, and selenium. Soil salinity problems in the San Joaquin Valley are intensified by poor soil drainage, insufficient water supply for adequate leaching, poor quality (high salinity) irrigation water, high water table, and an arid environment.

Soil salinity has been recognized as a problem in the San Joaquin Valley since the 1800s. The first problems were encountered between 1870 and 1915, when a rapid increase in irrigated acreage coincided with increasingly poor drainage and elevated salinity levels in the western and southern portions of the San Joaquin Valley. Between 1915 and the 1930s, an agricultural boom and formation of irrigation districts increased drainage and salinity problems to a community level. It was not until the 1920s that deep well pumping lowered the water table below the root zone of plants on the east side of the valley. Dry farming practices were replaced with irrigated agriculture on the west side in the 1940s, leading to the advent of drainage problems on the west side of the valley and near the valley trough in the 1950s.

Drainage and soil salinity problems have persisted in the San Joaquin Valley. A 1984 study (Backlund and Hoppes) estimated that about 2.4 million of the 7.5 million acres of irrigated cropland in the Central Valley were salt-affected. These saline soils generally exist in the valley trough and along the west side of the San Joaquin Valley. Additional studies, including the San Joaquin Valley Drainage Program studies, have recognized that a comprehensive salt management program is needed for the San Joaquin Valley. The 1990 San Joaquin Valley Drainage Program Management Plan projected that by year 2000 918,000 acres of San Joaquin Valley farmland would be affected by a high water table existing less than five feet from the ground surface. This projection indicates a 20 percent increase in acreage affected by high groundwater table from 1990 acreage levels. The increase was most prominent in the Westlands, Kern, and Tulare areas of the San Joaquin Valley. In addition, the 1991 San Luis Unit Drainage Program Draft Environmental Impact Statement projected losses of between 5,000 to 10,000 acres to increase in salinity by the year 2007 if current irrigation, farming, and drainage practices were to continue. Soil salinity occurs when salts, concentrated in the high groundwater table, are left behind as water evaporates from the soil surface. The drainage and soil salinity problem is discussed in the Groundwater Technical Appendix.

Soil Selenium

Soil selenium is primarily a concern on the west side of the San Joaquin Valley. When the soils on the west side are irrigated, selenium and other salts and trace elements dissolve and leach into the shallow groundwater. Figure II-2 shows selenium levels in the top 12 inches of soil as determined by a survey in the mid 1980s. Soils derived from the Sierra Nevada on the east side of the valley are less salty and contain much less selenium. Over the past 30 to 40 years of irrigation, soluble selenium has been leached from the soils into shallow groundwater (San Joaquin Valley Drainage Program, 1990).



Source: SJVDP, 1990.

FIGURE II-2

SELENIUM CONCENTRATIONS IN SOIL

Selenium found in soils and groundwater may have come from the interfan area between the Panoche-Cantua Creek fans (Tidbal et al., 1990). Mudflow deposits, rather than alluvium derived from the interior of the Diablo Range, may be the present source of much of the selenium. The original source of selenium is unknown, but may be associated with the geologic processes that were responsible for the major mercury mineralization present in an area located about 20 miles southwest of the San Joaquin Valley (New Idria Area).

In areas with high selenium concentrations, selenium leached from the soils enters the return flows and subsurface drainage flows. The selenium occurs in areas with poor drainage and high soil salinity concentrations, which reduces the effectiveness of leaching to remove the salts from these soils. Due to the slow percolation rate from the shallow groundwater aquifer to the upper groundwater aquifer created by a clay lens located beneath the shallow (groundwater aquifer) zone, the effectiveness of leaching to remove the salts is diminished. To maintain agricultural production, drainage from these soils must be removed from the area. The San Joaquin Valley Drainage Program was established as a joint federal and state effort to investigate drainage and related problems and identify possible solutions. The first step included construction of the first reaches of the San Luis Drain. Water collected by the drain was characterized by high selenium concentrations. Currently, Reclamation and the irrigators are developing a program to reduce selenium concentrations in the subsurface drainage flows and return flows as part of the Grasslands Bypass program, as discussed in the Surface Water and Water Facilities and Supplies technical appendices.

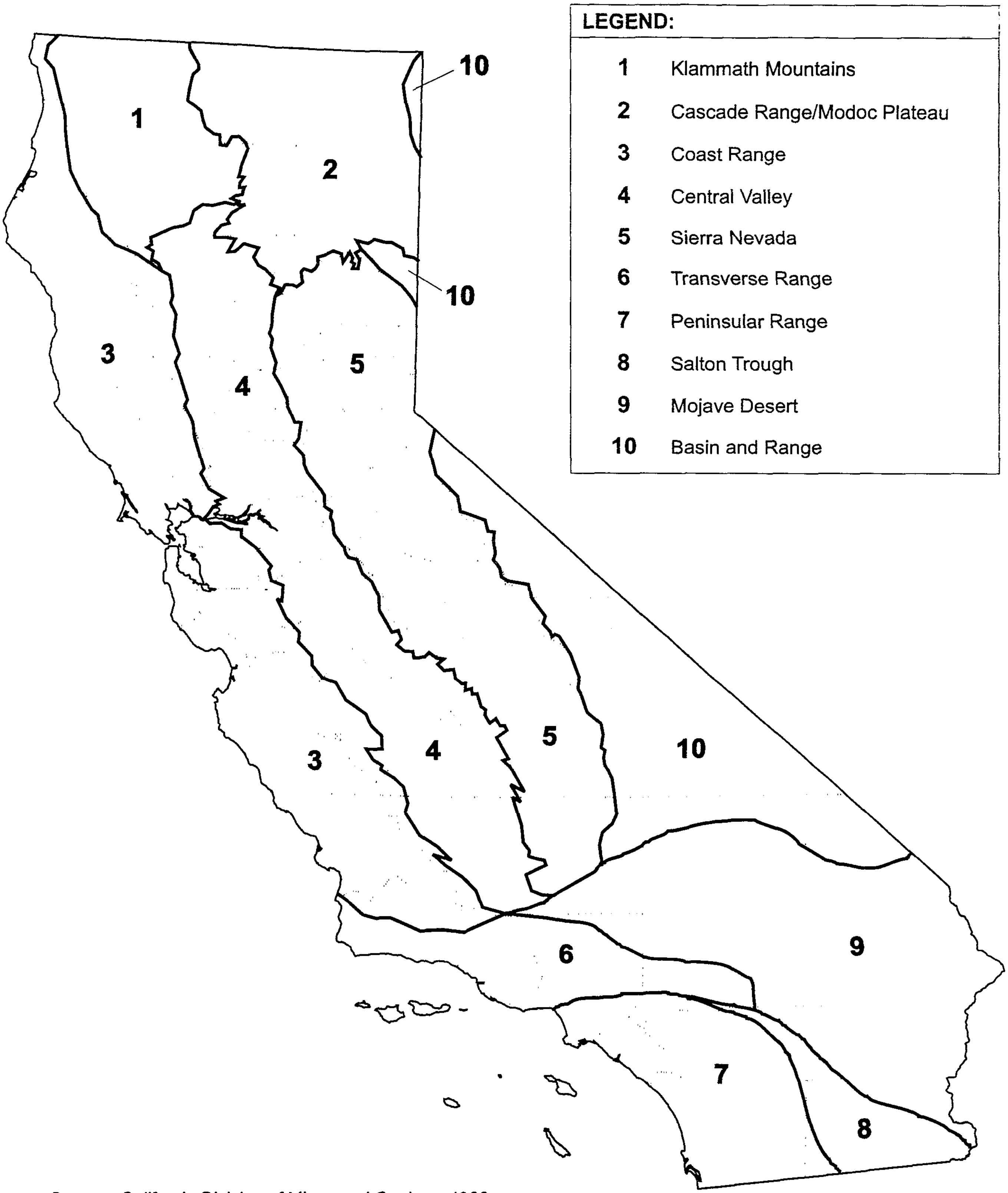
GEOLOGY CONDITIONS

Different geologic processes acting on various rock types over millions of years have created many geologically different areas within the state. Each area is considered a geologic province. Eleven geologic provinces are present at least partly in the state. From north to south, they are the Coast Range, Klamath Mountains, Cascade Range, Modoc Plateau, Central Valley, Sierra Nevada, Basin and Range, Mojave Desert, Transverse Range, Peninsular Range, and the Salton Trough. The study area for this investigation includes parts of the first six provinces mentioned. Figure II-3 shows all the geologic provinces in the state in relation to the subregions within the study area. A description of the six geologic provinces within the study area follows.

Coast Range

The Coast Range Province extends 600 miles from the Oregon-California border in the north to the Transverse Range in southern California. As its name suggests, the Coast Range parallels the California coast along the Pacific Ocean and extends inland 20 to 80 miles. The tectonically active province consists of parallel series of mountain ranges and structural valleys.

The Coast Range is dominated by the parallel series of mountain ranges and fault-controlled valleys. The Calaveras and Hayward faults are northwest-trending faults in the central Coast Ranges. The San Andreas fault is a northwest-trending fault in the northern, central and southern Coast Ranges. The faults of the Coast Range are generally northwest-trending, strike-slip faults with predominately right-lateral displacement with some vertical offset. Intense faulting and folding has created the mountain ranges of the Coast Ranges. The mountain ranges parallel



Source: California Division of Mines and Geology, 1966.

FIGURE II-3

GEOLOGIC PROVINCES

the faults and lie between major fault systems. The Mendocino Range in the northern Coast Range is one of the longer and higher ranges with some of the peaks reaching 6,000 feet. The Diablo Range lies west of the San Joaquin Valley and extends from Mt. Diablo southeast to the Kettleman Hills. Mt. Tamalpais is the northern extension of the Santa Cruz Mountains, which continue southward down the San Francisco Peninsula to Monterey Bay. The San Francisco Bay is a structural depression between the Diablo Range on the east and the Santa Cruz Mountains on the west. The Salinas Valley is the longest continuous valley in the province. It is bounded by the Gabilian Range on the east side and the Santa Lucia Range on the west.

The Coast Range consists of Mesozoic marine sedimentary and meta-sedimentary rocks that have undergone intense folding and faulting. Mesozoic granitic rocks are exposed in the Gabilan Range and the Santa Lucia Range. Some Cenozoic volcanic rocks are exposed in the Napa and Sonoma valleys and in the Diablo Range east of Hollister.

Klamath Mountains

The Klamath Mountain Province covers about 12,000 square miles of northwestern California between the Coast Range on the west and the Cascade Range on the east. The Klamath Mountains consist of a number of individual mountain ranges that trend more northward. The mountains consist of Paleozoic meta-sedimentary and meta-volcanic rocks and Mesozoic igneous rocks. These mountains may be a northwest extension of the Sierra Nevada, although the connection is obscured by the younger alluvial deposits of the Central Valley and the volcanic flows of the Cascade Range and the Modoc Plateau. Thompson Peak located in the Trinity Alps rises to an elevation of 8,936 feet, and is the tallest mountain peak in the Klamath Mountains. Although the peaks of the Klamath Mountains are lower than those of the Sierra Nevada, some of the higher peaks in the Trinity Alps have been glaciated.

The Klamath Mountains have a very complex geology. The province is primarily formed by several accurate mountain belts consisting of the eastern Klamath Mountain belt, central metamorphic belt, the western Paleozoic and Triassic, and the western Jurassic belt. Between the belts, low-angle thrust faults allow eastern blocks to be pushed westward and upward. The Klamath Mountain belt consists of up to 40,000 feet of eastward dipping Ordovician to Jurassic marine deposits. The central metamorphic belt contains Paleozoic hornblend and mica schists and ultramafic rocks. The western Jurassic, Paleozoic and Triassic belts consist of slightly metamorphosed sedimentary and volcanic rocks.

Cascade Range/Modoc Plateau

The Cascade Range and Modoc Plateau are presented together because of their geologic similarity. Together they cover about 13,000 square miles of the northeast corner of California. This is a geologically young province with a large variety of volcanic rocks. The Cascade Range includes the composite volcanoes, which in California include Mt. Shasta and Mt. Lassen. Mt. Lassen erupted intermittently between 1914 and 1917, making it the only California volcano active in this century. Evidence indicates that Mt. Shasta erupted during the eighteenth century. The Cascade Range composite volcanoes extend north to British Columbia. Peaks include Mt. McLoughlin, Crater Lake, the Three Sisters, Mt. Jefferson, and Mt. Hood in Oregon, and Mt. Adams, Mt. St. Helens, Mt. Rainer, and Mt. Baker in Washington. In California, the Cascade

Range/Modoc Plateau Province borders the Klamath Mountains to the west, the Central Valley to the southwest, and the Sierra Nevada to the south.

The Cascade volcanics have been divided into the Western Cascade series and the High Cascade series. The Western Cascade series consists of Miocene-aged basalts, andesites, and dacite flows interlayered with rocks of explosive origin including rhyolite tuff, volcanic breccia, and agglomerate. This series is exposed at the surface in a belt 15 miles wide and 50 miles long from the Oregon border to the town of Mt. Shasta. After a short period of uplift and erosion that extended into the Pliocene, volcanism resumed creating the High Cascade volcanic series. The High Cascade series forms a belt 40 miles wide and 150 miles long just east of the Western Cascade series rocks. Early High Cascade rocks formed from very fluid basalt and andesite that extruded from fissures to form low shield volcanoes. Later eruptions during the Pleistocene had a higher silica content, causing more violent eruptions. Large composite cones like Mt. Shasta and Mt. Lassen had their origins during the Pleistocene.

The Modoc Plateau consists of a high plain of irregular volcanic rocks of basaltic origin. The numerous shield volcanoes and extensive faulting on the plateau give the area more relief than may be expected for a plateau. The Modoc Plateau averages 4,500 feet in elevation and is considered a small part of the Columbia Plateau, which covers extensive areas of Oregon, Washington, and Idaho.

Sierra Nevada

The Sierra Nevada is the tallest and most continuous mountain range in California. It extends northwest for more than 400 miles. The Sierra Nevada extends west below the Central Valley province. On the north it is bound by the Cascade Range and Modoc Plateau. To the south it is separated from the Transverse Range by the Garlock Fault. East of the Sierra Nevada the Basin and Range extend east to Utah. In the southern Sierra Nevada, Mt. Whitney, the tallest mountain in the contiguous United States, rises 14,494 feet (USGS map data) above sea level. In contrast, Death Valley, the lowest point in the United States at elevation 282 feet below sea level (USGS map data), lies approximately 90 miles to the east.

The Sierra Nevada Province is generally composed of Mesozoic Sierran granitic batholith and associated older metamorphic rocks. In some areas of the northern Sierra Nevada, Tertiary sediments and volcanics overlie the igneous core. The Sierra Nevada resembles a tilted plateau that is depressed on the west side with the eastern side elevated. The Sierra Nevada batholith rises from beneath the sediments of the Central Valley at 3 to 5 degrees to its highest point in eastern peaks before it abruptly drops off along a fault escarpment. This fault marks the eastern end of the Sierra Nevada and the western limit of the Basin and Range Province.

Central Valley

The Central Valley is discussed in more detail than the other geologic provinces. The Central Valley Province is composed of tertiary sediments and volcanics, and is a northwest-trending asymmetric trough 400 miles long and averaging 50 miles wide. It is bound on the west by the pre-Tertiary and Tertiary semi-consolidated to consolidated marine sedimentary rocks of the Coast Range. The faulted and folded sediments of the Coast Range extend eastward beneath most of the Central Valley. The east side of the valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada.

Pre-Tertiary marine sediments account for about 25,000 feet of the total amount of sediments deposited in the sea before the rise of the Coast Range. Marine deposits continued to fill the Sacramento Valley until the Miocene Epoch and portions of the San Joaquin Valley until the late Pliocene, when the last seas receded from the valley. Then continental alluvial deposits from the Coast Range and the Sierra Nevada began to collect in the newly formed valley. In total, the Sacramento and San Joaquin valleys are filled with about 10 and 6 vertical miles of sediment, respectively.

The valley floor is divided into several geomorphic land types including dissected uplands, low alluvial fans and plains, river flood plains and channels, and overflow lands and lake bottoms. The dissected uplands consist of consolidated and unconsolidated continental deposits of Tertiary and Quaternary that have been slightly folded and faulted.

The alluvial fans and plains consist of unconsolidated continental deposits that extend from the edges of the valleys toward the valley floor. The alluvial plains cover most of the valley floor and make up some of the intensely developed agricultural lands in the Central Valley. Alluvial fans along the Sierra Nevada consist of high percentages of clean, well sorted gravel and sand. Fans from Coast Range streams are less extensive. West side fans tend to be poorly sorted and contain high percentages of fine sand, silt, and clay. Interfan areas between major alluvial fans of the east side are drained by smaller intermittent streams similar to those in the west side. Thus, they tend to be poorly sorted and have lower permeabilities than main fan areas. In general, alluvial sediments of the western and southern parts of the Central Valley tend to have lower permeability than east side deposits.

River flood plains and channels lie along the major rivers and to a lesser extent the smaller streams that drain into the valley from the surrounding Coast Range and Sierra Nevada. Some flood plains are well-defined where rivers are incised into their alluvial fans. These deposits tend to be coarse and sandy in the channels and finer and silty in the flood plains.

Lake bottoms of overflow lands include historic beds of Tulare Lake, Buena Vista Lake, and Kern Lake as well as other less defined areas in the valley trough. Near the valley trough, fluvial deposits of the east and west sides grade into fine-grained deposits. Extensive lake bed deposits are not present in the Sacramento Valley. The San Joaquin Valley has several thick lakebed deposits. The largest lake deposits in the Central Valley are found beneath the Tulare Lake bed where up to 3,600 feet of lacustrine and marsh deposits form the Tulare Formation. This formation is composed of widespread clay layers, the most extensive being the Cocoran Clay member which is found in the western and southern portions of the San Joaquin Valley. The Cocoran Clay member is a confining layer that separates the upper semi-confined to unconfined aquifer from the lower confined aquifer.

Several secondary geologic structures are found within the Central Valley. The Red Bluff Arch in the northern end of the Sacramento Valley consists of a series of northeast-trending anticlines and synclines, which act as a groundwater barrier between the Sacramento Valley and the Redding Basin. East of Colusa in the central part of the Sacramento Valley, the Sutter Buttes rise 2,000 feet above the valley floor. The Sutter Buttes are a remnant of a volcanic cone 10 miles in diameter.

In the San Joaquin Valley, a faulted ridge known as the Stockton Arch extends from the Sierra Nevada to the northern Diablo Range. Along the west side of the San Joaquin Valley, the faulting and folding of the adjacent Coast Range is present in the Central Valley in the Kettleman Hills, Elk Hills, Lost Hills, and Buena Vista Hills. The northeast-trending White Wolf Fault is believed to be part of the Bakersfield Arch, which is located in the southern end of the valley.

GEOLOGICAL-RELATED ISSUES OF CONCERN

Land Subsidence

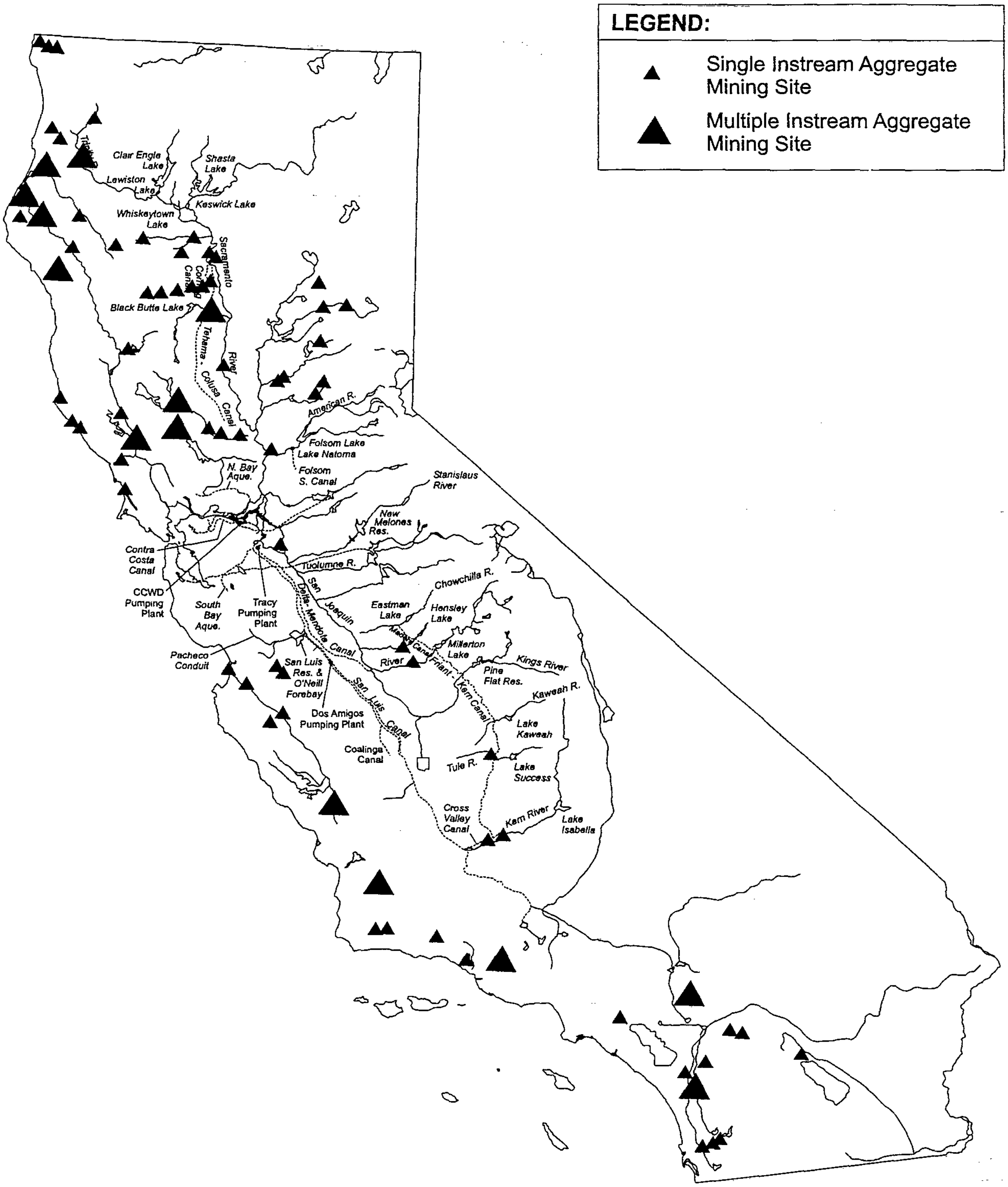
Subsidence occurs in the Delta, western San Joaquin Valley, and portions of the Central Sacramento Valley. Subsidence in the Delta is due to the compaction and disappearance of the organic soils, as discussed above. Subsidence in the San Joaquin and Sacramento valleys occurs because of reduced groundwater elevations and the related compaction of the soil interstitial spaces that had previously been filled with groundwater. Land subsidence has caused significant reductions in ground elevations. This issue is discussed in detail in the Groundwater Technical Appendix.

Instream Gravel Mining

Aggregate removal, or mining, occurs within many streams in the western foothills of California, as shown in Figure II-4. Generally, these rivers or streams are located along natural troughs of gravel and sand deposits. Aggregate mining also occurs along the coastal streams and in the coastal dunes. Unconsolidated gravels and slates also are mined in the lower foothills of the Sierra Nevada foothills. Because of the proximity of these deposits to the ground surface and because these deposits are located on flat land, these deposits have been mined for many years. The aggregate is primarily used for building and road materials.

Instream gravel mining causes significant water quality and habitat problems due to increased sediments in the river as well as removal of soils with nutrients and vegetation in the area of the mining activities. Increased sedimentation may affect both the tributary stream where the aggregate mining occurs and the main stream reach. Exposure of soils and minerals to water can leach chemicals from those sediments, causing potential toxicity problems in those receiving waters. Sedimentation can adversely affect survival of fish in streams due to increased stream turbidity, increased sedimentation of spawning gravels that reduces inter-gravel flow, potential reduction in dissolved oxygen, and increased potential for algal growths due to the reduction in light penetration through the water column. Instream gravel mining also removes spawning gravel and habitat. Finally, instream gravel mining creates multiple channels along or adjacent to the streambed. Many of the channels may be considered "dead-ends" or end in shallow pools which may be characterized by high temperatures or high sediments. This "braiding" of channels can cause navigation problems or entrainment of fish.

In recognition of potential problems caused by instream gravel mining, Shasta and Tehama counties have enacted gravel mining ordinances that serve to protect critical spawning areas.



Source: California State Lands Commission, 1993.

FIGURE II-4

INSTREAM AGGREGATE MINING SITES

CHAPTER III

ENVIRONMENTAL CONSEQUENCES

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Chapter III

ENVIRONMENTAL CONSEQUENCES

This chapter compares the impacts of Alternatives 1 through 4 to the No-Action Alternative with respect to the soils and geology of the study area.

IMPACT ASSESSMENT METHODOLOGY

The impact assessment of soils and geology is based upon two impact methodologies: (1) changes in agricultural land use, such as cropping patterns, land retirement, and fallowing, which may result in increased erosion potential, and (2) increased river flows and land subsidence, which may result in increased bank erosion and associated siltation problems. The changes in agricultural land use and river flows are discussed in the Agricultural Economics and Land Use Technical Appendix and Surface Water Supplies and Facilities Operations Technical Appendix, respectively. Land subsidence is discussed in the Groundwater Technical Appendix. Drainage and soil salinity and selenium problems are discussed in the Affected Environment. Because the alternatives do not result in changes in river flows or major changes in irrigated acreage in other portions of the Study Area, the impact assessment is focused on the Central Valley portion of the PEIS Study Area.

NO-ACTION ALTERNATIVE

The No-Action Alternative is the base condition for the PEIS alternatives analyses. The No-Action Alternative represents conditions in the future assuming a projected 2022 level of development without implementation of CVPIA.

Under the No-Action Alternative, surface water availability would be reduced to CVP and SWP contractors relative to recent conditions. In addition, land use projections presented in the California Department of Water Resources (DWR) Bulletin 160-93 indicate that some water rights holders will increase irrigated acreage. Most of the reduction in the use of surface water is projected to be replaced by groundwater. As a result, cropping patterns would be similar to historic conditions resulting in little change in erosion potential under the No-Action Alternative.

Under the No-Action Alternative, 45,000 acres of poorly drained irrigated land is projected to be retired based on the San Joaquin Valley Drainage Program recommendations (SJVDP). It is assumed that lands to be retired or fallowed would be reseeded with grasses and grazed by livestock or occasionally dryfarmed, as discussed in the Vegetation and Wildlife Technical Appendix. Cultivation measures similar to those historically used on fallowed lands will prevent runoff and wind erosion in addition to historical conditions. As a result, land retirement as projected will cause little change in erosion potential under the No-Action Alternative.

Operational criteria for reservoir release fluctuations and ramping under the No-Action Alternative are the same as described in the Affected Environment. These operational criteria take into consideration bank erosion and siltation potential, and are defined to minimize these impacts. Therefore, stream bed erosion will be similar to historical conditions.

ALTERNATIVE 1

Water management provisions in Alternative 1 were developed to utilize two of the tools provided by CVPIA, Re-operation and 3406 (b)(2) Water Management, toward meeting the target flows for chinook salmon and steelhead trout in the Central Valley streams. In addition, Alternative 1 assumed retirement of 30,000 acres of poorly drained irrigated lands in accordance with the San Joaquin Valley Drainage Study.

EROSION POTENTIAL DUE TO CHANGES IN CROPPING PATTERNS

The water management actions under Alternative 1 would primarily affect CVP water supplies. It is anticipated that reductions in CVP water supplies would be replaced by increases in groundwater pumping. Reduction in surface water supply availability under Alternative 1 would result in fallowing of irrigated lands in the Central Valley. Combined with land retirement, the overall reduction in irrigated acreage under Alternative 1 as compared to the No-Action Alternative would be less than 1 percent of the irrigated acreage in the Central Valley.

It is assumed that the lands to be retired or fallowed would be reseeded with grasses and grazed by livestock or occasionally dryland farmed, as discussed in the Vegetation and Wildlife Technical Appendix. These cultivation measures are similar to methods used on lands which have been historically fallowed due to crop rotation or periodic cropping pattern changes. Therefore, due to relatively minor changes in land use and to continuation of dryland farmed cultivation practices, it is anticipated that the level of erosion potential will not increase under Alternative 1 as compared to the No-Action Alternative.

EROSION POTENTIAL DUE TO CHANGES IN STREAMFLOWS

Under Alternative 1, increased river releases would be in accordance with target flows which include flow ramping limitations to protect aquatic species and prevent siltation due to bank erosion. In addition, the flow pattern will not result in release oscillations on a month to month basis, so potential for sloughing will not be increased. Continued application of stream flow considerations in reservoir operations will apply under Alternative 1 and will not result in additional stream bed erosion relative to the No-Action Alternative.

On Clear Creek, the flows would increase 25 to 300 percent above existing flows, depending upon the water year type and month. This increase in flow under Alternative 1 could increase erosion potential if the habitat restoration activities identified in Alternative 1 were not implemented. However, with full implementation of Alternative 1, including the habitat restoration activities and increased flows, erosion potential would not increase as compared to the No-Action Alternative.

Land subsidence, due to groundwater level declines, will occur along the west side of the San Joaquin Valley. Land subsidence on the west side of the Tulare Lake Region will have a geographically limited effect on soil erosion and deposition because it does not contain extensive stream and river drainage as part of the PEIS.

ALTERNATIVE 2

Alternative 2 includes the acquisition of water to meet salmon and steelhead target flows, primarily in April through June. These acquisitions are limited by the amount of funds assumed to be available in the CVPIA Restoration Fund. This water acquisition will increase flows in the Stanislaus, Tuolumne, and Merced rivers.

EROSION POTENTIAL DUE TO CHANGES IN CROPPING PATTERNS

It is assumed that the lands to be retired or fallowed would be reseeded with grasses and grazed by livestock or occasionally dryland farmed, as discussed in the Vegetation and Wildlife Technical Appendix. These cultivation measures are similar to methods used on lands which have been historically fallowed due to crop rotation or periodic cropping pattern changes. Therefore, due to relatively minor changes in land use and to continuation of dryland farmed cultivation practices, it is anticipated that the level of erosion potential will not increase under Alternative 2 as compared to the No-Action Alternative.

EROSION POTENTIAL DUE TO CHANGES IN STREAMFLOWS

Under Alternative 2, increased river releases would be in accordance with target flows which include flow ramping limitations to protect aquatic species and prevent siltation due to bank erosion. In addition, the flow pattern will not result in release oscillations on a month to month basis, so potential for sloughing will not be increased. Continued application of stream flow considerations in reservoir operations will apply under Alternative 2 and will not result in additional stream bed erosion relative to the No-Action Alternative.

On Clear Creek, the flows would increase 25 to 300 percent above existing flows, depending upon the water year type and month. This increase in flow under Alternative 2 could increase erosion potential if the habitat restoration activities identified in Alternative 2 were not implemented. However, with full implementation of Alternative 2, including the habitat restoration activities and increased flows, erosion potential would not increase as compared to the No-Action Alternative.

Land subsidence, due to groundwater level declines, will occur along the west side of the San Joaquin Valley. Land subsidence on the west side of the Tulare Lake Region will have a geographically limited effect on soil erosion and deposition because it does not contain extensive stream and river drainage as part of the PEIS.

ALTERNATIVE 3

Alternative 3 includes the acquisition of water to meet salmon and steelhead target flows, primarily in April through June. These acquisitions are limited by the amount of funds assumed to be available in the CVPIA Restoration Fund. This water acquisition will increase flows in the Stanislaus, Tuolumne, Calaveras, Mokelumne, Yuba and Merced rivers. In addition, under Alternative 3 more land will be retired than in Alternative 2 as a result of acquired water.

EROSION POTENTIAL DUE TO CHANGES IN CROPPING PATTERNS

It is assumed that the lands to be retired or fallowed would be reseeded with grasses and grazed by livestock or occasionally dryland farmed, as discussed in the Vegetation and Wildlife Technical Appendix. These cultivation measures are similar to methods used on lands which have been historically fallowed due to crop rotation or periodic cropping pattern changes. Therefore, due to relatively minor changes in land use and to continuation of dryland farmed cultivation practices, it is anticipated that the level of erosion potential will not increase under Alternative 3 as compared to the No-Action Alternative.

EROSION POTENTIAL DUE TO CHANGES IN STREAMFLOWS

Under Alternative 3, increased river releases would be in accordance with target flows which include flow ramping limitations to protect aquatic species and prevent siltation due to bank erosion. In addition, the flow pattern will not result in release oscillations on a month to month basis, so potential for sloughing will not be increased. Continued application of stream flow considerations in reservoir operations will apply under Alternative 3 and will not result in additional stream bed erosion relative to the No-Action Alternative.

On Clear Creek, the flows would increase 25 to 300 percent above existing flows, depending upon the water year type and month. This increase in flow under Alternative 3 could increase erosion potential if the habitat restoration activities identified in Alternative 3 were not implemented. However, with full implementation of Alternative 3, including the habitat restoration activities and increased flows, erosion potential would not increase as compared to the No-Action Alternative.

Land subsidence, due to groundwater level declines, will occur along the west side of the San Joaquin Valley. Land subsidence on the west side of the Tulare Lake Region will have a geographically limited effect on soil erosion and deposition because it does not contain extensive stream and river drainage as part of the PEIS.

ALTERNATIVE 4

Under Alternative 4, flows will be increased and land will be retired similarly to Alternative 3.

EROSION POTENTIAL DUE TO CHANGES IN CROPPING PATTERNS

It is assumed that the lands to be retired or fallowed would be reseeded with grasses and grazed by livestock or occasionally dryland farmed, as discussed in the Vegetation and Wildlife Technical Appendix. These cultivation measures are similar to methods used on lands which have been historically fallowed due to crop rotation or periodic cropping pattern changes. Therefore, due to relatively minor changes in land use and to continuation of dryland farmed cultivation practices, it is anticipated that the level of erosion potential will not increase under Alternative 4 as compared to the No-Action Alternative.

EROSION POTENTIAL DUE TO CHANGES IN STREAMFLOWS

Under Alternative 4, increased river releases would be in accordance with target flows which include flow ramping limitations to protect aquatic species and prevent siltation due to bank erosion. In addition, the flow pattern will not result in release oscillations on a month to month basis, so potential for sloughing will not be increased. Continued application of stream flow considerations in reservoir operations will apply under Alternative 4 and will not result in additional stream bed erosion relative to the No-Action Alternative.

On Clear Creek, the flows would increase 25 to 300 percent above existing flows, depending upon the water year type and month. This increase in flow under Alternative 4 could increase erosion potential if the habitat restoration activities identified in Alternative 4 were not implemented. However, with full implementation of Alternative 4, including the habitat restoration activities and increased flows, erosion potential would not increase as compared to the No-Action Alternative.

Land subsidence, due to groundwater level declines, will occur along the west side of the San Joaquin Valley. Land subsidence on the west side of the Tulare Lake Region will have a geographically limited effect on soil erosion and deposition because it does not contain extensive stream and river drainage as part of the PEIS.

CHAPTER IV

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Chapter IV

BIBLIOGRAPHY

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CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT TECHNICAL APPENDIX

Groundwater

September 1997

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LIST OF ABBREVIATIONS AND ACRONYMS

AEWSD	Arvin-Edison Water Storage District
cfs	cubic feet per second
CVGSM	Central Valley Groundwater-Surface Water Simulation Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DBCP	dibromochloropropane
Delta	Sacramento-San Joaquin Delta
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
MCL	maximum contaminated level
μg/l	micrograms per liter
mg/l	milligrams per liter
msl	mean sea level
MWD	Metropolitan Water District of Southern California
PEIS	Programmatic Environmental Impact Statement
Reclamation	U.S. Bureau of Reclamation
RWQCB	Regional Water Quality Control Board
SCVWD	Santa Clara Valley Water District
SJVDP	San Joaquin Valley Drainage Program
SSWD	South Sutter Water District
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
YCFCWD	Yolo County Flood Control and Water District

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Draft Programmatic Environmental Impact Statement (PEIS) summarizes the evaluation of the direct and indirect impacts of implementing a wide range of actions identified in the Central Valley Project Improvement Act (CVPIA). Details of the information used in the definition of the affected environment and analysis of the environmental consequences are presented in the technical appendices of the Draft PEIS.

This technical appendix presents a summary of groundwater conditions, including background information that was used during the PEIS preparation, and the results of the impact analyses for groundwater conditions that occurred throughout the study area.

The groundwater analysis was primarily based upon changes in available water supplies and stream flows as presented in the Surface Water and Facilities Operations Technical Appendix and changes in agricultural land use practices as presented in the Agricultural Economics and Land Use Technical Appendix.

The assumptions and results of the analyses for Alternatives 1, 2, 3, and 4 and of Supplemental Analyses 1a and 1d are presented in this technical appendix and summarized in the Draft PEIS. The assumptions and results of Supplemental Analyses 1b, 1c, 1e through 1i, 2a through 2d, 3a, and 4a are summarized only in the Draft PEIS. The assumptions related to the groundwater analyses for Alternatives 1, 2, 3, and 4 and for the Supplemental Analyses 1a and 1d are presented in Table I-1. The results of the analyses are presented in Table I-2.

TABLE I-1

SUMMARY OF ASSUMPTIONS FOR GROUNDWATER ANALYSES

Alternative or Supplemental Analysis	Assumption
No-Action Alternative	Continued use of groundwater per California Department of Water Resources projections in Bulletin 160-93 and economic considerations.
1	Same as No-Action Alternative plus: Increase groundwater withdrawals to replace reductions in CVP deliveries due to implementation of (b)(2), level 2 refuge water supplies, and increased Trinity River instream fishery flows. Decrease groundwater withdrawals in response to implementation of San Joaquin Valley Drainage Program land retirement recommendations.
1a	Increase groundwater withdrawals to replace reductions in CVP deliveries due to implementation of (b)(2) water in the Delta.
1d	Increase groundwater withdrawals due to reductions in CVP deliveries.
2	Same as Alternative 1 plus: No increase in groundwater withdrawals to replace acquired surface water. No acquisition of groundwater.
3	Same as Alternative 2 plus: No increase in groundwater withdrawals to replace acquired surface water. No acquisition of groundwater.
4	Same as Alternative 3 plus: No increase in groundwater withdrawals to replace acquired surface water. No acquisition of groundwater. Increase groundwater withdrawals to replace reductions in CVP deliveries due to implementation of (b)(2) water in the Delta.

TABLE I-2

SUMMARY OF IMPACT ASSESSMENT OF GROUNDWATER

Affected Factors	No-Action Alternative	Alternative 1	Supplemental Analysis 1a	Supplemental Analysis 1d	Alternative 2	Alternative 3	Alternative 4
		Change from No-Action Alternative					
Average depth to groundwater (ft)							
Sacramento River Region (West)	94	No change	No change	+1 (+1%)	+1 (+1%)	+1 (+1%)	+1 (+1%)
Sacramento River Region (East)	100	+2 (+2%)	+2 (+2%)	+2 (+2%)	+2 (+2%)	+5 (+5%)	+5 (+5%)
San Joaquin River Region	85	+1 (+2%)	+3 (+4%)	+2 (+3%)	+2 (+3%)	+3 (+4%)	+4 (+5%)
Tulare Lake Region (North)	200	+9 (+3%)	+13 (+5%)	+10 (+4%)	+10 (+4%)	+3 (+1%)	+12 (+5%)
Tulare Lake Region (South)	313	-4 (-1%)	-2 (-1%)	-4 (-1%)	-4 (-1%)	-11 (-3%)	-2 (-1%)
Long-Term Change in Subsidence							
Sacramento River Region	Increase above existing conditions near Davis-Zamora	Same as No-Action Alternative	Same as No-Action Alternative	Same as No-Action Alternative	Same as No-Action Alternative	Same as No-Action Alternative	Same as No-Action Alternative
San Joaquin River Region	Increase above existing conditions on westside	Increase from No-Action Alternative	Increase from No-Action Alternative	Same as No-Action Alternative	Similar to Alternative 1	Increase from No-Action Alternative; less than Alternative 1	Similar to Alternative 1
Tulare Lake Region	Increase above existing conditions on westside	Increase from No-Action Alternative	Increase from No-Action Alternative	Same as No-Action Alternative	Similar to Alternative 1	Increase from No-Action Alternative; less than Alternative 1	Increase from Alternative 1

CHAPTER II

AFFECTED ENVIRONMENT

Chapter II

AFFECTED ENVIRONMENT

INTRODUCTION

This chapter identifies the groundwater resources that could be affected by implementation of the CVPIA. It has been prepared for use as background and support information for the PEIS.

Detailed site-specific information on all groundwater basins and subbasins potentially affected by CVPIA is not included in this chapter. Rather, it presents general information on the regional groundwater resources directly affected by CVP operations, those targeted for specific action by the CVPIA (such as the doubling of the anadromous fish population), and all regional groundwater aquifers included in the numerical models used to simulate groundwater system responses for the PEIS. This analysis, in combination with the discussion of groundwater hydrologic modeling processes (included in the CVGSM Methodology/Modeling Technical Appendix), provides an analysis of groundwater conditions that would be associated with implementation of the CVPIA.

Groundwater resources are described at various levels of detail, with emphasis on the Central Valley regional aquifer system. Distinguishing characteristics of this system are discussed for the Sacramento River, San Joaquin River, and Tulare Lake regions (see Figure II-1). The discussion of groundwater conditions includes hydrogeology, groundwater storage and production, groundwater levels, land subsidence, groundwater quality, agricultural subsurface drainage, and seepage-induced waterlogging of farm lands. Groundwater resources of the San Francisco Bay Region are also discussed in this chapter for areas receiving CVP project water supplies, specifically Santa Clara, San Benito, Alameda, and Contra Costa counties. Impacts to groundwater resources in this region are discussed qualitatively in Chapter III. The level of detail presented in this chapter for this region is in support of this qualitative level of analysis.

Since a usable groundwater quality model was not available, groundwater quality conditions that would be associated with implementation of the CVPIA will not be quantified. A general qualitative discussion of groundwater quality conditions will be presented.

A historical perspective of the period 1922 through 1992 identifies changing conditions of groundwater resources.

DATA SOURCES

Historical and recent information for this technical appendix was collected from the U.S. Geological Survey (USGS), California Department of Water Resources (DWR), U.S. Bureau of Reclamation (Reclamation), California State Water Resources Control Board (SWRCB), California Regional Water Quality Control Boards (RWQCBs), the San Joaquin Valley Drainage Program (SJVDP), and related investigations.

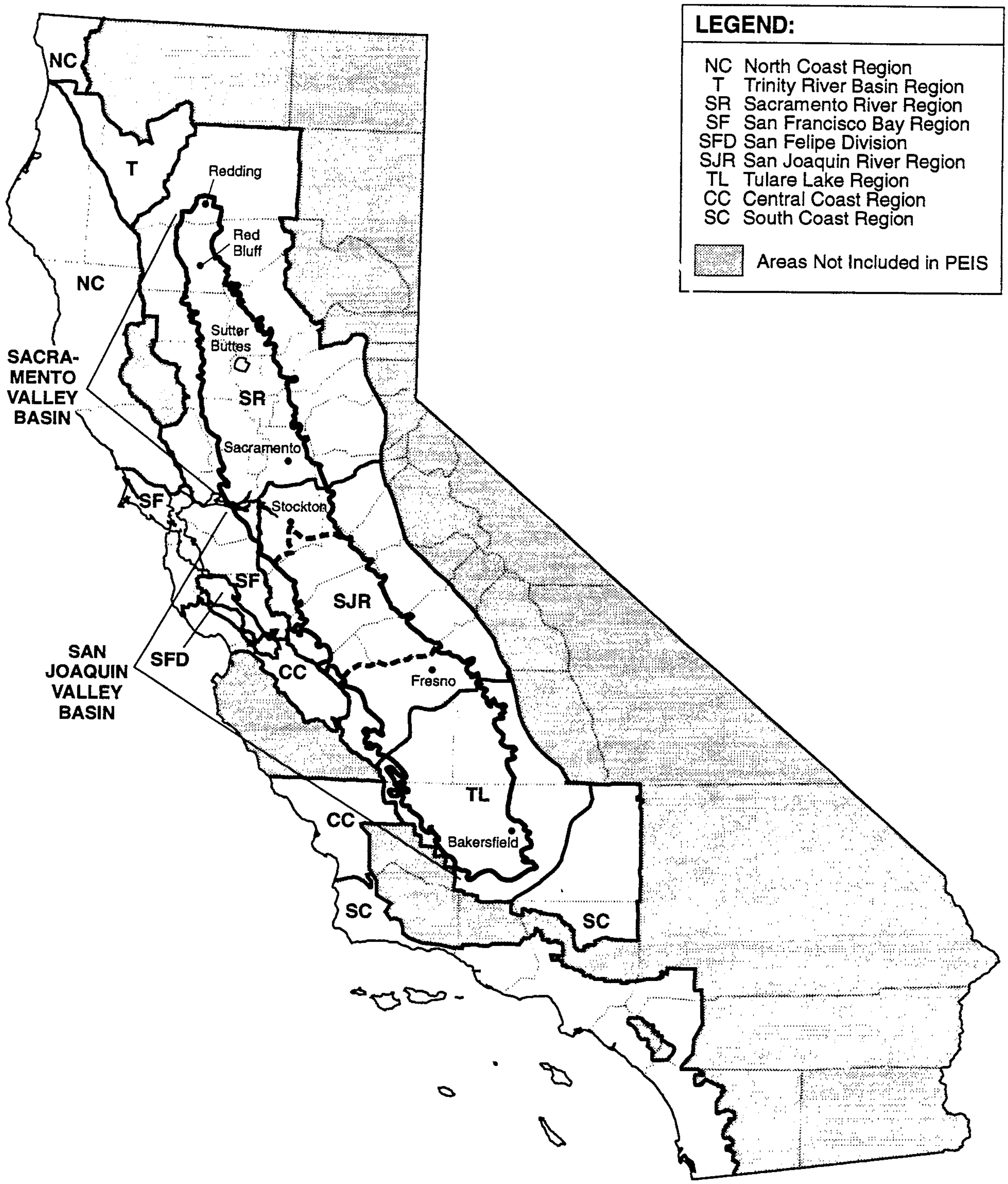


FIGURE II-1
GROUNDWATER STUDY AREA

Recent USGS reports were used to describe land subsidence conditions in the Central Valley. Since 1956, USGS has been researching this problem in cooperation with the DWR. The discussion of land subsidence in the Santa Clara Valley is based on information provided in a Final Environmental Impact Statement prepared by Reclamation for the San Felipe Unit of the CVP.

Recent groundwater quality conditions were summarized from the most recent Water Body Fact Sheets prepared by the SWRCB for the biennial Water Quality Assessment (SWRCB, 1991) and a summary of groundwater quality in the Central Valley prepared for the USGS (Bertoldi et al., 1991).

Recent agricultural drainage information was summarized from the SJVDP. Additional information was collected from the Central Valley RWQCB.

HISTORICAL PERSPECTIVE AND RECENT CONDITIONS

Groundwater resources of the Central Valley are described with regard to regional hydrogeology, groundwater storage and production, groundwater levels, and groundwater quality. The discussion of groundwater quality covers those parameters of concern that affect agricultural productivity and others that are noted to be in high concentrations and known to affect human health and wildlife, including: total dissolved solids (TDS), boron, nitrates, arsenic, selenium, and dibromochloropropane (DBCP).

In addition, three other issues related to groundwater conditions, agricultural drainage associated with shallow groundwater, seepage-induced waterlogging of farm lands, and land subsidence caused by groundwater level declines, are discussed. Agricultural subsurface drainage has historically been affected by the presence of perched shallow groundwater conditions in parts of the Central Valley. Seepage-induced waterlogging of farm land has historically occurred due to the movement of water from the stream into an adjacent shallow groundwater aquifer. Land subsidence may be caused by one or a combination of the following mechanisms:

- compaction of aquifer sediments, resulting from groundwater overdrafting and lowering of the hydraulic head in the aquifer system;
- compaction of sediments in petroleum reservoir rocks caused by oil and gas exploration and extraction;
- hydrocompaction (the compaction of moisture-deficient sediments following the first application of water);
- compaction of peat soils following land drainage; and
- tectonic subsidence (Bertoldi et al., 1991).

Historically, the greatest occurrence of land subsidence in the Central Valley has resulted from groundwater overdraft and lowering of the hydraulic head, and is the only type of land subsidence discussed in this technical appendix. Other types of induced land subsidence would not be further exacerbated by the implementation of the CVPIA.

OVERVIEW OF THE CENTRAL VALLEY REGIONAL AQUIFER SYSTEM

The Central Valley regional aquifer system of California is a 400-mile long, northwest-trending asymmetric trough averaging 50 miles in width. The location and geologic boundary of this aquifer system are shown in Figure II-1.

The significant water-producing geologic units are the unconsolidated to semi-consolidated non-marine sediments that range from the Oligocene and Miocene ages (13 million to 25 million years old) to recent, and are located in the valley trough. The west side of the trough is bounded by pre-Tertiary and Tertiary semi-consolidated to consolidated marine sedimentary rocks of the Coast Ranges. These faulted and folded sediments extend eastward beneath most of the Central Valley; any water contained in the sediments is usually saline. The east side of the valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada. Only small quantities of water are extracted from the joints and cracks of these basement rocks.

Many faults and folds exist in the Central Valley. Available information suggests that most faults and folds do not obstruct groundwater flow. The Red Bluff Arch, the White Wolf Fault, and the Sutter Buttes are the only significant groundwater barriers within the Central Valley. The Red Bluff Arch is located in the northern end of the Sacramento River Region separating the Redding groundwater basin from the Sacramento Valley groundwater basin. The White Wolf Fault, located in the southeastern corner of the Tulare Lake Region, inhibits the northward flow of groundwater. The Sutter Buttes, located near the center of the Sacramento River Region, are the eroded remains of a Plio-Pleistocene Age volcano. In the vicinity of this impervious geologic structure, southward groundwater flow is generally diverted to the east and west sides of the volcanic formation.

The hydrogeology and groundwater conditions associated with the Central Valley aquifer system are discussed in more detail below as part of the regional discussions.

GROUNDWATER RESOURCES OF THE SACRAMENTO RIVER REGION

The northern third of the Central Valley regional aquifer system is located in the Sacramento River Region. Referring to Figure II-1, this region extends from north of Redding to the Sacramento-San Joaquin Delta (Delta) in the south. DWR identifies this area of the aquifer as the Sacramento Valley basin and the Redding basin (California DWR, 1975), together covering over 5,500 square-miles. For the purposes of this technical appendix, references made to the Sacramento Valley basin are assumed to include the Redding basin.

Hydrogeology

During the geologic period of deposition, as much as 10 vertical miles of unconsolidated continental and marine sediment accumulated in the structural trough of the Sacramento Valley basin. Alluvium deposits can be found throughout the region in the form of alluvial fans, stream channel deposits, and flood plain deposits. These vast deposits are the source of most of the groundwater pumped in the Sacramento Valley. Although the Sacramento Valley Aquifer System is considered unconfined, areas of confinement are present. Depth to the base of freshwater ranges from 1,000 feet in the Orland area to nearly 3,000 feet in the Sacramento area. These and other geohydrologic features are shown in Figure II-2 as two generalized cross-sections for the Sacramento River Region.

Aquifer recharge of the basin has historically occurred from deep percolation of rainfall, the infiltration from stream beds, and subsurface inflow along basin boundaries. Most of the recharge for the Central Valley occurs in the north and east sides of the valley where the precipitation is the greatest. With the introduction of agriculture to the region, aquifer recharge was augmented by deep percolation of applied agricultural water and seepage from irrigation distribution and drainage canals.

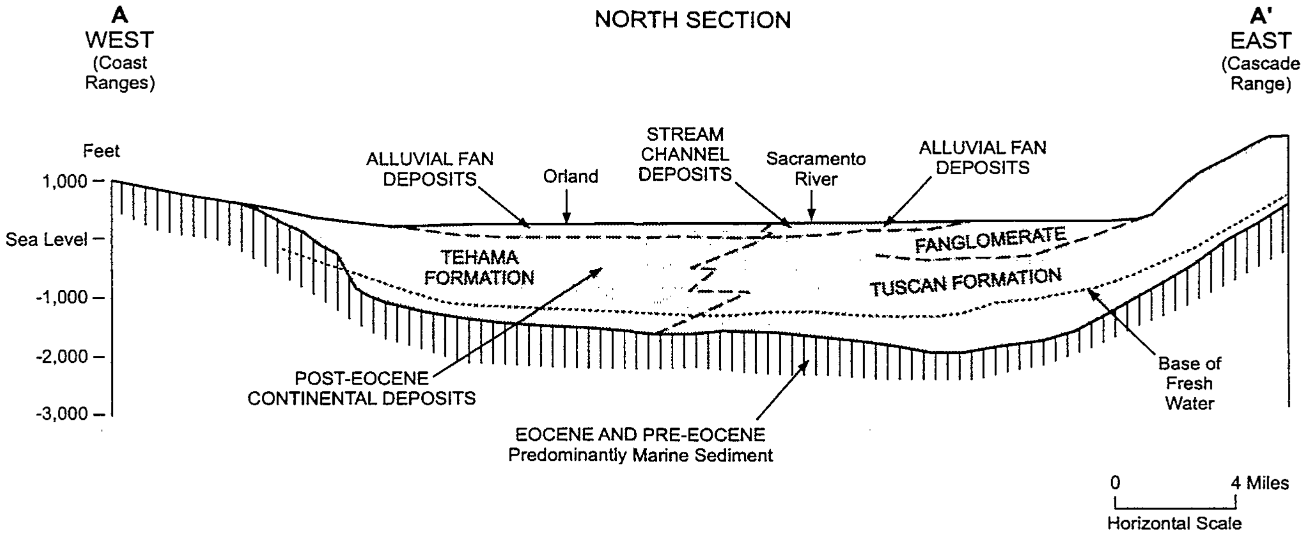
In the Sacramento River Region, a dynamic link between the groundwater and surface water system has been maintained on a regional basis. The greatest gains to streams from groundwater occurred during the 1940s when groundwater storage was highest in the Sacramento Valley basin. Gains to streams was lowest during and immediately following the 1976 to 1977 drought and the 1987 to 1992 drought. In some areas to the south of the region, such as Sacramento County, where groundwater levels have continued to decline, streams that formerly gained flow from the groundwater now lose flow through seepage to adjacent groundwater systems.

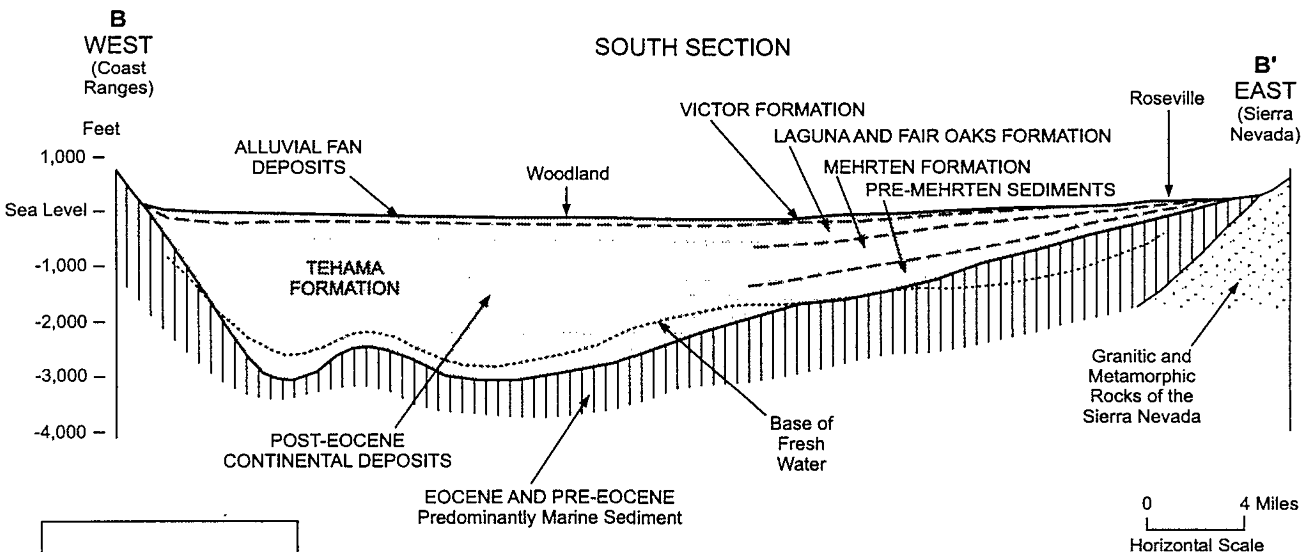
During pre-development conditions, the groundwater flow was from the flanks to the valley axis, then south toward the Delta. However, recent development and the associated increased pumping have induced changes in natural groundwater flow patterns. In areas of the region where groundwater pumping has increased more than other areas, such as areas within Sacramento, Yolo, and Solano counties, groundwater movement is now toward areas of groundwater depression.

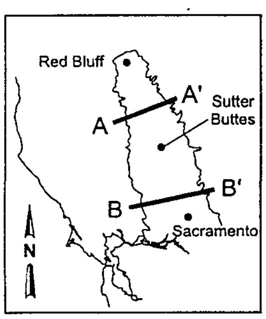
Groundwater Storage and Production

There have been several estimates of the amount of groundwater associated with the Sacramento Valley basin. The USGS estimated approximately 33.5 million acre-feet of groundwater storage capacity between 20 and 200 feet of the ground surface (Bryan, 1923). In DWR's most recent California Water Plan Update (Bulletin 160-93), usable storage capacity was estimated to be 40 million acre-feet (DWR, 1994). The difference between these estimates is a function of the definition of "usable storage capacity." Rather than defining usable storage capacity based on a depth range, DWR's definition is based on aquifer properties (i.e., permeability), groundwater quality, and economic considerations such as the cost of well drilling and energy costs (DWR, 1994). The USGS estimates are considered to be conservative since present day definitions of usable capacity could include groundwater available below 200 feet of the ground surface.

Safe yield is a concept commonly used in describing a groundwater basin. The definition of safe yield can include several factors, but in general it defines the amount of groundwater a basin can produce without promoting an undesirable result. In recent efforts by DWR, groundwater has been characterized by its perennial yield, or "... the amount of groundwater that can be extracted without lowering groundwater levels over the long-term." (DWR, 1994). This perennial yield is







Source: Adapted from DWR, 1978.

FIGURE II-2

GENERALIZED GEOHYDROLOGICAL CROSS-SECTIONS IN THE SACRAMENTO RIVER REGIONS

directly dependent upon the amount of recharge received by the groundwater basin, which may be different in the future than it has been in the past. There have been numerous attempts to define the amount of safe yield, and more recently perennial yield, of the Sacramento Valley basin. The estimates vary depending upon the methodology used and the assumptions that are made. The most recent estimate, developed by DWR for the California Water Plan Update (Bulletin 160-93) and referred to as perennial yield, is 2.4 million acre-feet.

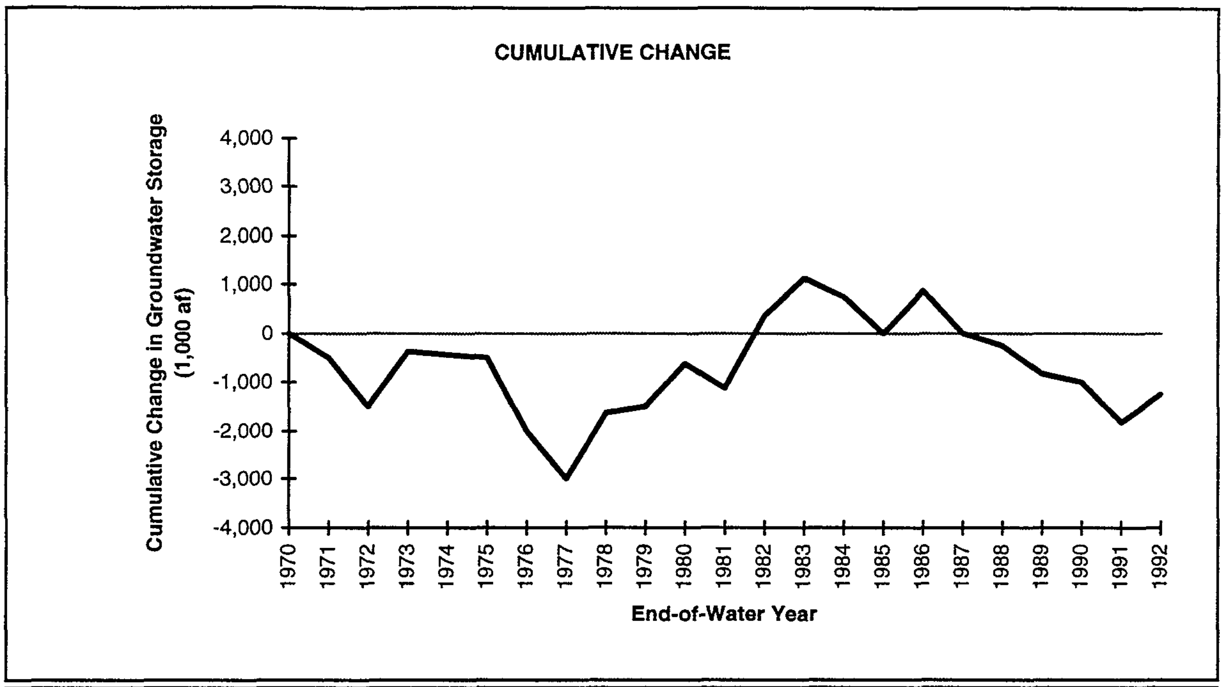
Groundwater storage reacts to changes in pumping and natural recharge, and the contribution from applied irrigation water, leaky conveyance facilities (facilities intended to convey water and recharge groundwater), and artificial recharge. The effects of these changing conditions on groundwater storage can span several years, and if the changes are large, can result in permanent change over the long-term. The change in groundwater storage for the Sacramento River Region from 1970-to-1992 is shown in Figure II-3. This figure shows that relative to conditions in 1970, groundwater storage in the Sacramento River Region declined during the 1970s, with the greatest reduction in 1977, recovered in the wet period of the early 1980s, and dropped again during the 1987-to-1992 drought period. Although the storage conditions fluctuate during this period, the basin has generally recovered and has not been subject to regional overdraft conditions.

Groundwater pumping and agricultural acreage for the historical period 1922 to 1980 are shown in Figure II-4. These data were developed as part of the Central Valley Ground-Surface Water Model (Reclamation et al., 1990). The groundwater pumping data is based on USGS estimated groundwater pumping, estimated water demands, and historical surface water supplies. The agricultural acreage data is based on DWR estimates developed as part of their depletion studies. This information is presented through 1980 based on the availability of regional groundwater pumping. Groundwater pumping has roughly paralleled changes in irrigated agricultural acreage from 1922 to 1980. From the 1920s to the 1940s, groundwater pumping for the Sacramento Valley basin ranged from 300,000 to 500,000 acre-feet. From the 1940s to the early 1980s, pumping increased steadily but varied considerably from year to year. Prior to the 1976-1977 drought, annual groundwater pumping totaled just less than 2 million acre-feet. During each of the two years of the drought, more than 2.5 million acre-feet were pumped from the ground. By 1980 groundwater pumping returned to pre-drought levels of 2 million acre-feet. Since the 1980s growth on the outskirts of concentrated urban areas, which historically have relied on local surface water rights, has contributed to an increase in groundwater pumping.

Recent estimates of groundwater pumping by DWR for the California Water Plan Update for 1990 conditions (normalized) suggest that 2.5 million acre-feet of groundwater pumping occurred in the Sacramento Valley basin. This is higher than the estimated perennial yield by approximately 33 thousand acre-feet, resulting in slight overdraft for these conditions (DWR, 1994). This slight overdraft condition is primarily associated with conditions in the southeastern portion of the region in the Sacramento County area.

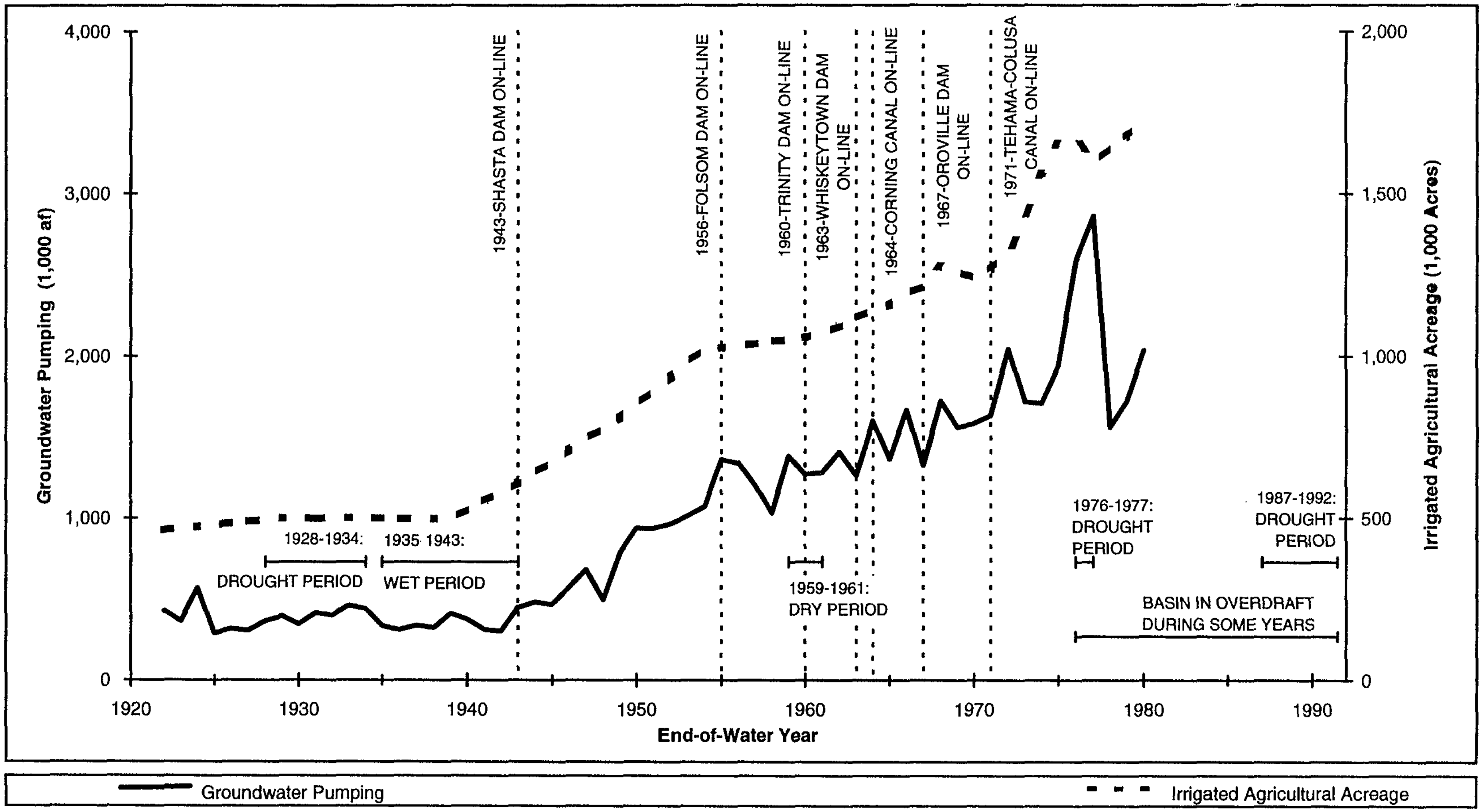
Groundwater Levels

In the Sacramento River Region, groundwater levels associated with the Sacramento Valley basin have historically declined moderately during extended droughts, generally recovering to



SOURCE:
DWR, 1994

FIGURE II-3
HISTORICAL CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR THE SACRAMENTO RIVER REGION (1970-1992)



NOTE:

Data available from 1922 to 1980. Data developed as part of the Central Valley Ground-Surface Water Model (Reclamation et al., 1990).

SOURCE:

Reclamation et al., 1990.

FIGURE II-4
HISTORICAL GROUNDWATER PUMPING AND IRRIGATED AGRICULTURAL ACREAGE FOR THE SACRAMENTO RIVER REGION

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pre-drought levels as a result of subsequent wetter periods. This recovery process may span several years, or may occur over a single year, depending upon the extent of the wet period.

In 1913, 1,664 groundwater wells were in operation irrigating nearly 41,000 acres in the Sacramento Valley (Bryan, 1923). Available information for this period (groundwater levels reported by USGS between 1903 and 1910) show groundwater gradients sloping from the edge of the Sacramento Valley downward to the valley floor. North of the Sutter Buttes groundwater levels for fall 1960 (reported by DWR) had remained relatively unchanged since the early 1900s. However, south of the Sutter Buttes groundwater levels in several areas of Yolo, Solano, and Sacramento counties had dropped nearly 50 feet since the early 1900s.

Groundwater levels for spring 1974 (reported by Reclamation) showed very little change since 1960 for areas north of the Sutter Buttes. East of the Sutter Buttes, in the Marysville area, groundwater levels declined between 1960 and 1974 as a result of continued groundwater development in response to increasing agricultural water demands. Groundwater levels in the Solano-Yolo County area had increased approximately 25 feet between 1960 and 1974, a result of several years of above normal precipitation during the late 1960s and early 1970s and the introduction of surface water supplies from the Solano Project in 1960. In Sacramento and San Joaquin counties, groundwater levels in spring 1974 had continued to decline.

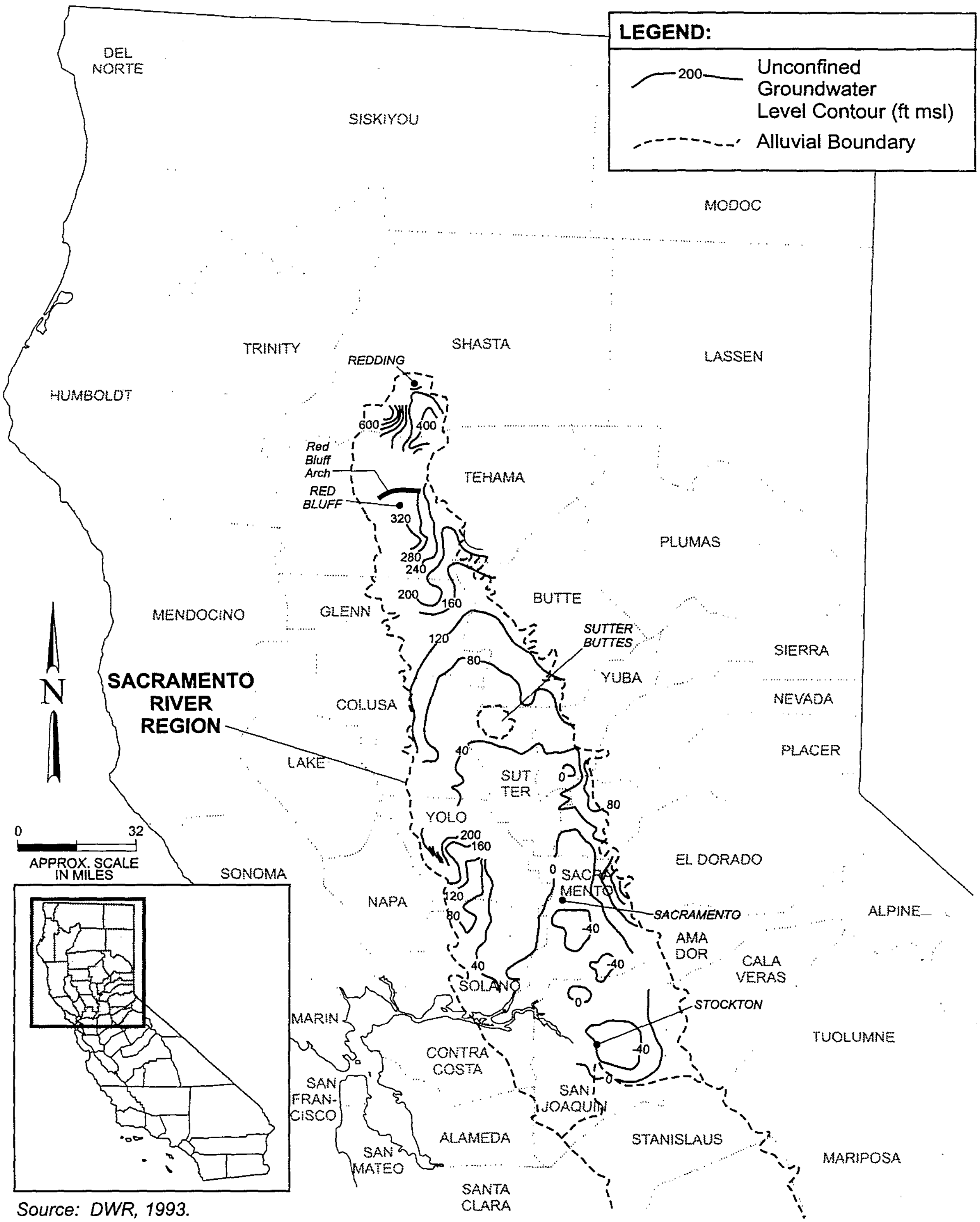
Groundwater levels for spring 1986 (reported by DWR) indicate little change east and north of the Sutter Buttes since 1974. Between 1974 and 1986 groundwater levels in the Solano-Yolo County area increased regionally by approximately 20 feet. The spring 1986 groundwater level conditions in Sacramento and San Joaquin counties showed that the pumping depression had stabilized, but large areas were still below sea level.

During the 1987-1992 drought, groundwater levels declined in Butte and Tehama counties; however, very little decline occurred in Glenn and Colusa counties (DWR, 1994). Post-drought groundwater conditions observed for spring 1993 (reported by DWR) are shown in Figure II-5. The spring 1993 groundwater contours indicate a pumping depression in Sacramento and San Joaquin counties, and that groundwater in much of the western part of these counties is more than 40 feet below sea level. In all other areas of the Sacramento Valley basin the above normal precipitation events occurring during the 1992-1993 winter months resulted in near full recovery of groundwater levels to pre-drought conditions.

Land Subsidence

The largest occurrence of land subsidence in the world induced by human activity occurs in California's Central Valley (Bertoldi et al., 1991). The areal extent of this land subsidence is shown in Figure II-6. The primary land subsidence occurring in the Central Valley corresponds to areas where groundwater levels have declined significantly due to mining of groundwater. Figure II-7 shows decreases in groundwater levels in the Central Valley from 1860 to 1961, demonstrating the relationship between declining groundwater levels and extensive areas of major land subsidence.

Land subsidence in the Sacramento Valley is localized and is concentrated in areas of pumping-induced groundwater overdraft. Areas using groundwater supply for irrigation are much less



Source: DWR, 1993.

FIGURE II-5

GROUNDWATER ELEVATIONS IN THE SACRAMENTO VALLEY, SPRING 1993

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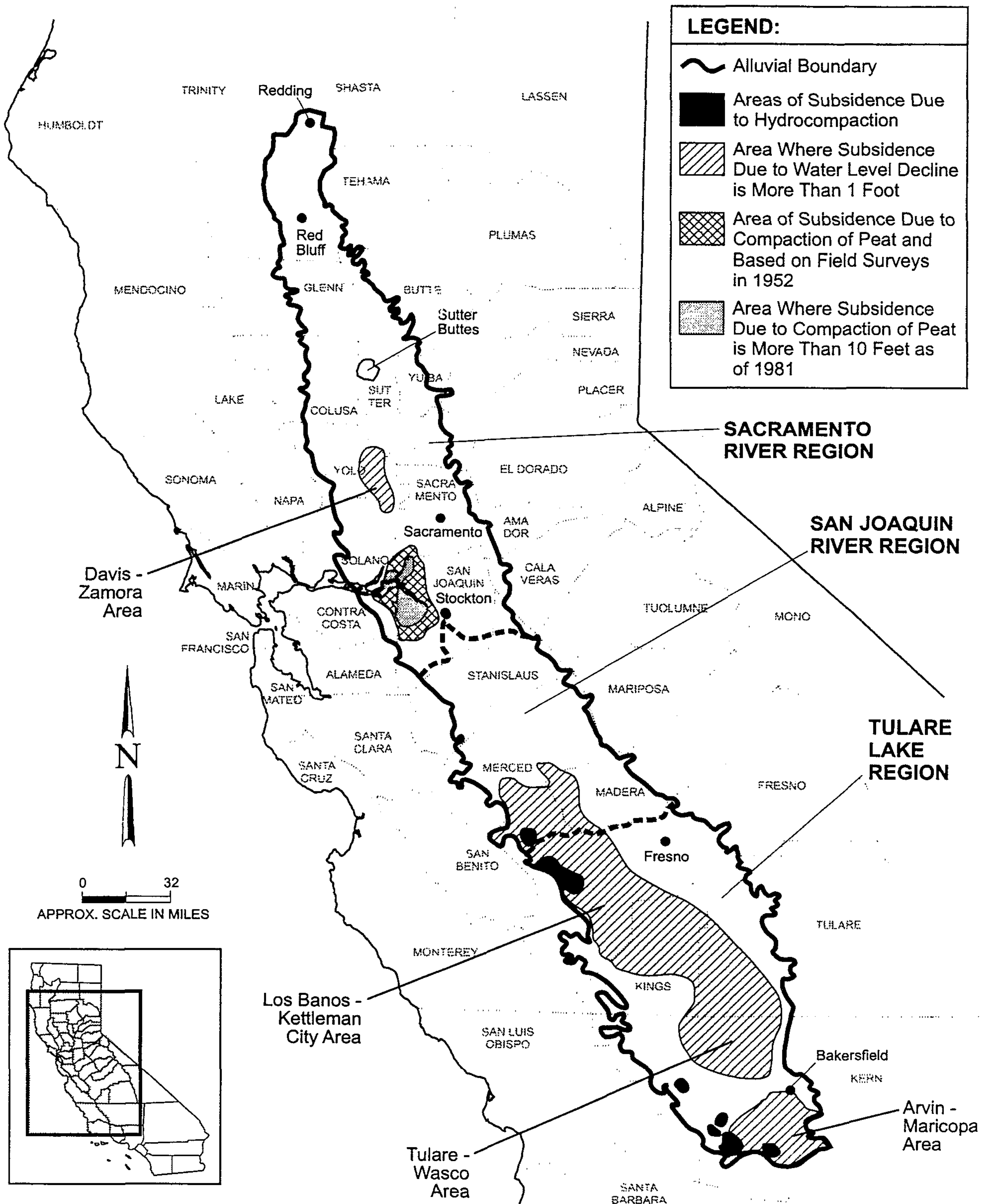
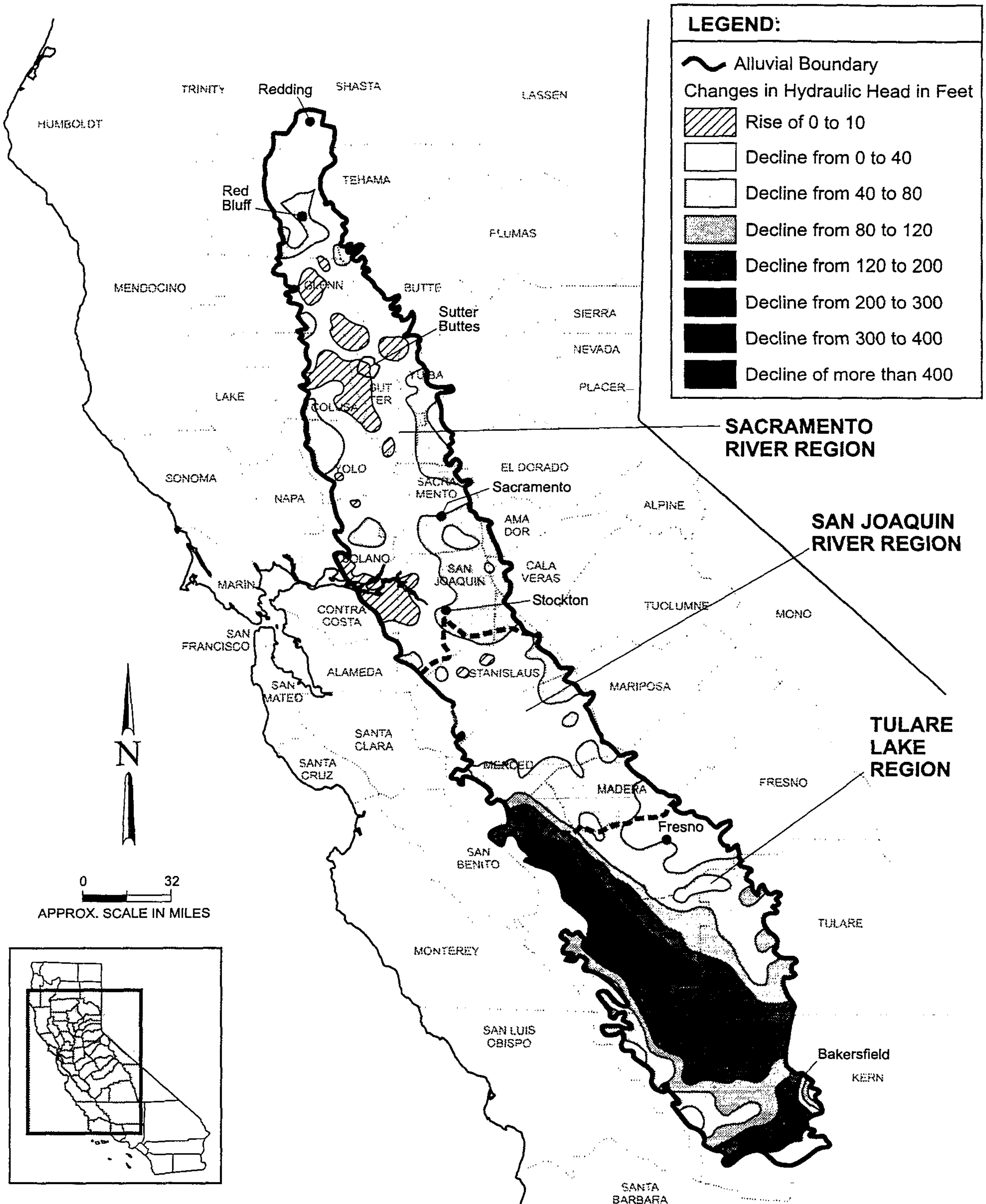


Source: Adapted from Bertoldi et al., 1991.

FIGURE II-6

AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY



Source: Adapted from Bertoldi et al., 1991.

FIGURE II-7

ESTIMATED CHANGES IN HYDRAULIC HEAD IN LOWER PUMPED ZONE FROM 1860 TO 1961

extensive in Sacramento Valley than in the San Joaquin Valley because of greater surface water availability. In addition, greater natural recharge in this area relative to the San Joaquin Valley results in less severe groundwater level declines. Consequently, the water level decline in most parts of the Sacramento Valley was much lower during the past 60 years of agricultural development. However, in a few localities, intensive groundwater pumping prior to 1969 caused the water levels to decline between 40 and 110 feet (Lofgren and Ireland, 1973).

A preliminary investigation of land subsidence in the Sacramento Valley was conducted in 1973 by Lofgren and Ireland. The investigation identified two main areas in the southwestern part of the valley, near Davis and Zamora, where land subsidence had exceeded 1 foot by 1973. Land subsidence in excess of 2 feet was measured by 1973 in the area east of Zamora and west of Arbuckle. The USGS also documented land subsidence in this area in excess of 1 foot by 1970 (see Davis-Zamora area shown in Figure II-8). Land subsidence monitoring has continued since 1973, and some localized land subsidence has been recorded in the Davis-Zamora area during the 1987 to 1992 drought period (Dudley, 1995).

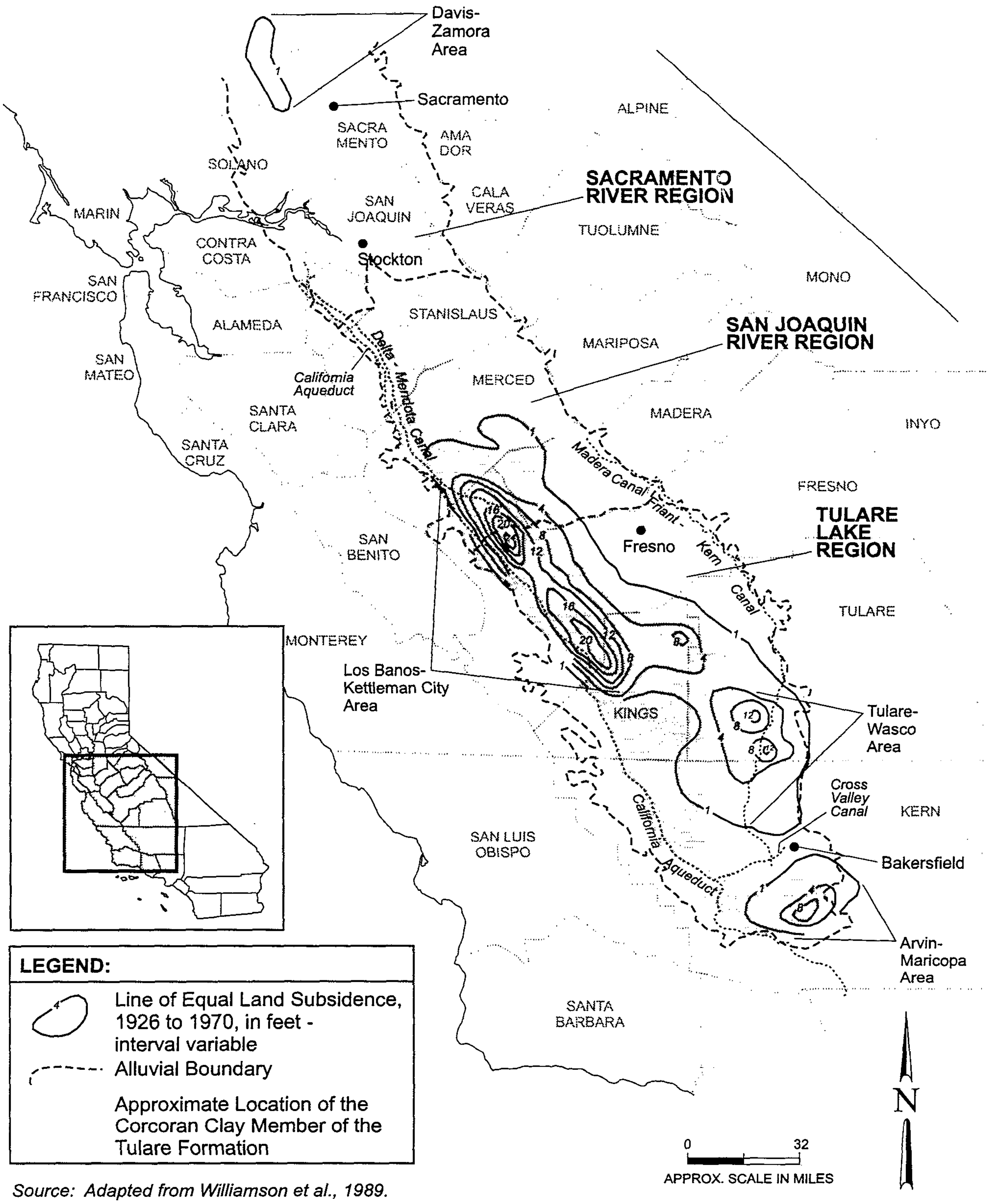
Groundwater Quality

Groundwater quality in the Sacramento River Region is generally excellent, however, there are areas with local groundwater contamination or pollution (DWR, 1994). Groundwater quality parameters included in this technical appendix are listed in Table II-1 and are discussed below for the Sacramento River Region. Table II-1 also lists the sources and reasons for concerns associated with these parameters. Only those parameters that are associated with regional problems are discussed here. Site-specific groundwater quality issues with unique conditions would not likely be affected by regional changes represented in the CVPIA PEIS. However, any future site-specific studies associated with the CVPIA may require more detailed assessment of these local issues.

Total Dissolved Solids. In a survey of changes in TDS concentrations in groundwater over time in the Sacramento Valley groundwater basin, increases were reported throughout the valley since the 1950s, with the exception of the area around the Sutter Buttes between the Sacramento and Feather rivers (Hull, 1984). However, TDS concentrations generally do not exceed 500 mg/l, and regionally TDS levels in groundwater have been lower in the Sacramento valley basin relative to concentrations in groundwater in other areas of the Central Valley.

Figure II-9 presents the most recent conditions summary of the areal distribution of TDS concentrations in groundwater of the Central Valley (Bertoldi et al., 1991). This map is a composite of data from existing wells with a wide variety of depths and screen lengths, and is a representation of likely TDS concentrations found in groundwater zones most commonly used. The map does not show vertical variations in TDS.

TDS concentrations are higher in the south-central part of the Sacramento River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates in the Cascade Range and the Sierra Nevada, and the predominant regional groundwater flow pattern. Two large areas of shallow groundwater in the southern portion of the region where concentrations of TDS in groundwater exceed 500 milligrams per liter (mg/l), and have been recorded as high as 1,500 mg/l, include areas south of the Sutter Buttes in the Sutter Basin and



Source: Adapted from Williamson et al., 1989.

FIGURE II-8

AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY DUE TO GROUNDWATER LEVEL DECLINE

C-080368

C-080370

TABLE II-1

GROUNDWATER QUALITY PARAMETERS OF CONCERN

Parameter	Source	Reasons For Concern	Drinking Water Standards (California and Federal) (mg/l)				Agricultural Water Quality Goals (mg/l)
			California Dept. Of Health Services		U.S. Environmental Protection Agency		
			Primary MCL	Secondary MCL	Primary MCL	Secondary MCL	
TDS	Naturally occurring in marine deposits.	Impaired municipal and irrigation uses	None	500 (1)	None	500	450
Boron	Naturally occurring in marine deposits.	Toxicity to agricultural crops in high concentrations	None	None	None	None	0.75 to 4.0 (2)
Nitrate	Naturally occurring; Fertilizer/sewage runoff.	Impaired plant development/ Human health issues	45 (as NO_3)	None	45 (as NO_3)	None	None
Arsenic	Naturally occurring in some marine deposits.	Plant and animal toxicity/ Suspected carcinogen	0.05	None	0.05	None	0.1
Selenium	Naturally occurring in marine deposits.	Toxicity to animals/Bio-accumulation in waterfowl	0.01	None	0.05	None	0.02 (3)
DBCP	Manufactured nematocide used as soil fumigant	Chronic and toxic effects on humans/animals	0.0002	None	0.0002	None	None

NOTES:

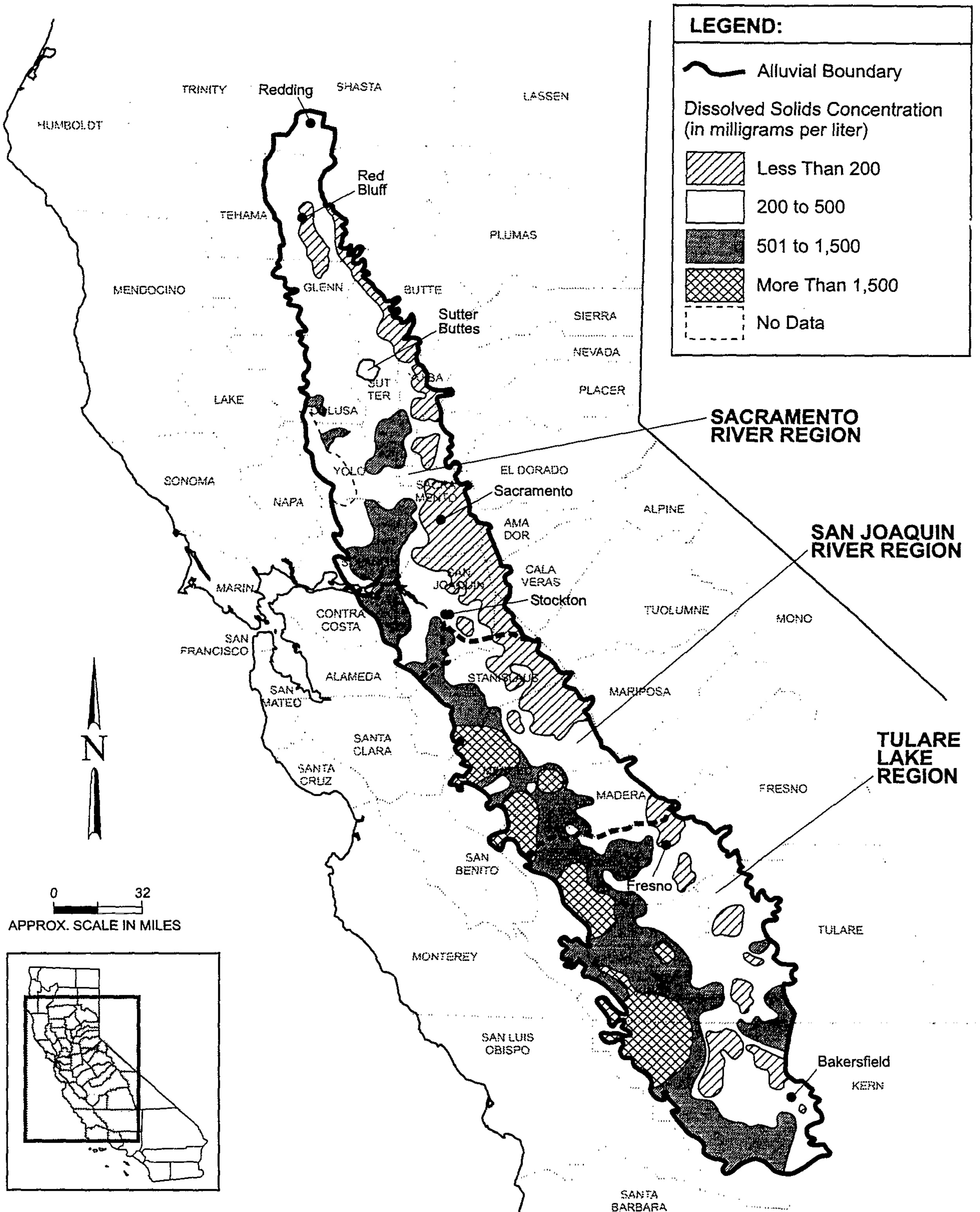
(1) California Domestic Water Quality Regulations allows a maximum of 1,000 mg/l if water of better quality is not available.
(2) >0.75 mg/l is toxic to sensitive plants species; >4.0 mg/l is toxic to most agricultural crops.
(3) Can concentrate in irrigation return water and be transported to sensitive water bodies.

SOURCES:

California Regional Water Quality Control Board, Central Valley Region, (1993)
Ayers, R.S., and D.W. Westcol (1985)

LEGEND:

MCL = Maximum contaminant level
mg/l = milligrams per liter



Source: Adapted from Bertoldi et al., 1991.

FIGURE II-9

TDS CONCENTRATIONS IN THE GROUNDWATER AQUIFER OF THE CENTRAL VALLEY

C-080370

C-080372

west of the Sacramento River extending from West Sacramento on the north to the confluence of the Sacramento and San Joaquin Rivers on the south (Bertoldi et al., 1991).

Boron. Boron is not a regulated substance in drinking water, but it is a critical element in irrigation water. In small quantities, boron is essential for plant growth. However, concentrations as low as 0.75 mg/l may be toxic to boron-sensitive plants, and it is toxic to most crops at concentrations above 4 mg/l (Bertoldi et al., 1991).

Low levels of boron (below 0.75 mg/l) have been observed in the area extending from Vacaville to West Sacramento, and south to Rio Vista. As shown in Figure II-10, boron concentrations greater than 0.75 mg/l have been reported in an area east of Red Bluff, and an area extending from Arbuckle on the north to Davis on the south (Bertoldi et al., 1991).

Nitrates. Nitrates are common contaminants in the groundwater of many rural communities in California and have become increasingly widespread due to agricultural activities and sewage disposal on or below the land surface. Nitrates can enter the groundwater through the conversion of naturally occurring or introduced organic nitrogen or ammonia.

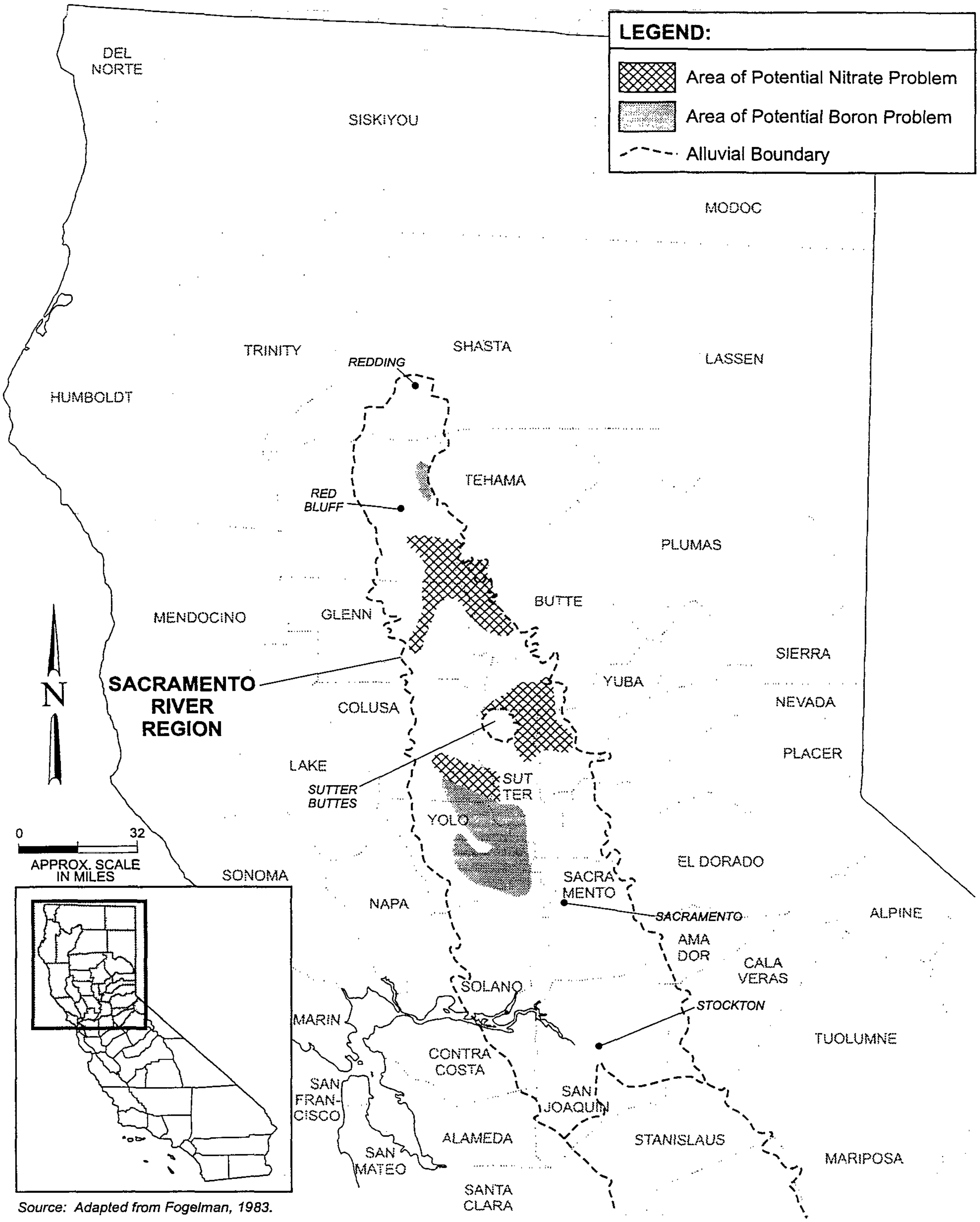
The U. S. Environmental Protection Agency (USEPA) primary drinking water standard for nitrate concentration in drinking water is 10 mg/l nitrate as NO_3 (NO_3-N) (Reclamation et al., 1990). Nitrate in irrigation water is usually considered an asset because of its value as a fertilizer. However, some crops such as sugar beets, apricots, grapes, citrus, and avocados may be adversely affected by high nitrate concentrations in certain stages of their growth cycle. Problems can result from concentrations as low as 5 mg/l (NO_3-N), and severe problems can result from concentrations above 30 mg/l (NO_3-N) (Bertoldi et al., 1991).

In a survey of changes in nitrate concentrations in groundwater over time in the Sacramento Valley basin, increases were reported on the west side and in the southeastern portion of the valley since the 1950s (Hull, 1984). Areas of recent potential nitrate problems in the Sacramento River Region are shown in Figure II-10. Maximum concentrations of more than 10 mg/l nitrate as $N0_3$ ($N0_3$-N) have been found throughout the valley. Concentrations exceeding 30 mg/l are rare and localized (Bertoldi et al., 1991).

Municipal use of groundwater as drinking water supply is impaired due to elevated nitrate concentrations in the Chico area of the Sacramento River Region (SWRCB, 1991).

Arsenic. Arsenic is a naturally occurring trace element in the Central Valley. Arsenic is regulated by the USEPA at a primary drinking water quality standard of 50 micrograms per liter (µg/l). It can be toxic to both plants and animals. For irrigation use, the guidelines recommend that arsenic concentrations not exceed 1,000 µg/l. There are no regional areas of elevated arsenic concentration levels in the Sacramento River Region (SWRCB, 1991).

Selenium. Selenium is a naturally occurring trace element in the Central Valley that is toxic to humans and animals at very low concentrations. Selenium is regulated by the USEPA at a primary drinking water quality standard of 50 µg/l and by the California Department of Health Services at a primary drinking water standard of 10 µg/l. The toxicity to fish and wildlife occurs



Source: Adapted from Fogelman, 1983.

FIGURE II-10

POTENTIAL NITRATE AND BORON PROBLEM AREAS IN THE SACRAMENTO VALLEY

through bioaccumulation. There are no regional areas of elevated selenium concentration levels in the Sacramento River Region (SWRCB, 1991).

Dibromochloropropane. Prior to 1979, DBCP was used as a nematocide (soil fumigant) in orchards and vineyards. Use of the nematocide was discontinued in 1979 because of the health hazard posed to humans and because of the potential for groundwater contamination resulting from high mobility in the soil. Prior to 1986, DBCP was not regulated. In 1986, DBCP was regulated at an maximum contaminated level (MCL) of 1.0 μg/l; and in 1989 a primary drinking water standard was imposed at an MCL of 0.2 μg/l. Concentrations above the detection limit have not been reported in the Sacramento River Region.

Agricultural Subsurface Drainage

High water tables contributing to problems of subsurface drainage water occur in several areas of the Sacramento River Region. The Colusa Basin Drain provides drainage and irrigation water for irrigated lands in the northwest part of the Sacramento River Region. High water tables exist in portions of Colusa County, particularly along the Sacramento River, periodically impairing subsurface drainage functions of the Colusa Basin Drain and other local drainage facilities.

Seepage and Waterlogging

In many reaches of the Sacramento River, flows are confined to a broad shallow manmade channel with stream bottom elevations higher than adjacent ground surface elevations. This condition, combined with areas where local groundwater is in contact with the river, places adjoining farm lands in danger of seepage-induced waterlogging damage during extended periods of high streamflows. This is especially true during spring and summer months, when crop roots are susceptible to damage by high groundwater and when farmers need to get equipment on the fields. DWR has conducted an in-depth investigation of the seepage problem, reported in Bulletin 125. The report contains curves relating crop damage to river flow for three reaches of the Sacramento River. Alternatives for mitigating the seepage problem were presented and evaluated at a reconnaissance level (DWR, 1967). In 1976 and 1977 Reclamation updated the 1965-level cost estimates presented in Bulletin 125 and conducted a reconnaissance-level evaluation of methods of resolving the problem (Reclamation, 1976a, 1977). To date none of these alternatives have been implemented.

GROUNDWATER RESOURCES OF THE SAN JOAQUIN RIVER REGION

The southern two-thirds of the Central Valley regional aquifer system extends from just south of the Delta to just south of Bakersfield, and is referred to as the San Joaquin Valley basin (DWR, 1975), covering over 13,500 square-miles. For the purposes of the PEIS analysis, this basin is divided into the San Joaquin River Region and the Tulare Lake Region. DWR further divides this basin into subbasins. Subbasins in the northern half of the San Joaquin Valley basin, lying within the San Joaquin River Region (Figure II-1), include the Tracy, Eastern San Joaquin County, Modesto, Turlock, Merced, Chowchilla, Madera, and Delta-Mendota subbasins (DWR, 1994).

Hydrogeology

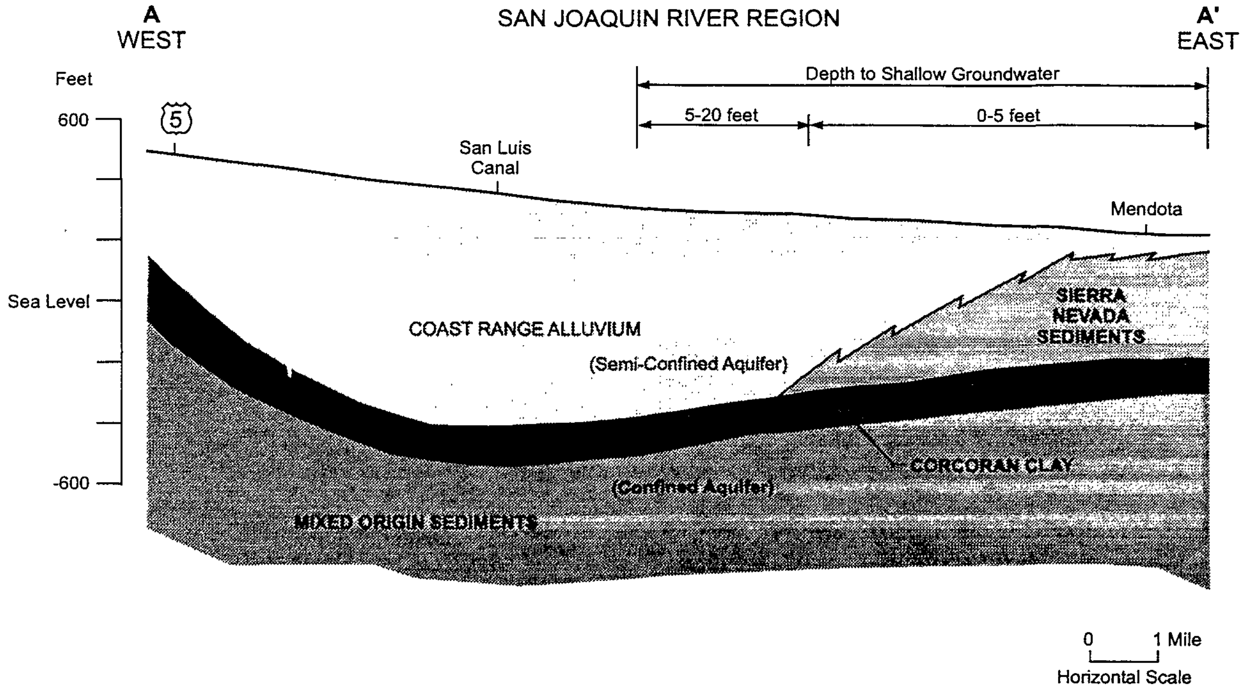
The San Joaquin Valley basin has accumulated up to 6 vertical miles of unconsolidated continental and marine sediment in the structural trough. The top 2,000 feet of these sediments consist of continental deposits that generally contain freshwater (Page, 1986). As these sediments accumulated over the last 24 million years, large lakes periodically filled and drained resulting in deposition of laterally extensive clay layers, forming significant barriers to the vertical movement of groundwater in the basin (Westlands Water District, 1995). The most extensive of these is the Corcoran Clay (a member of the Tulare Formation which was deposited about 600,000 years ago), consisting of a clay layer zero to 160 feet thick, found at depths of 100 to 400 feet below the land surface in the San Joaquin River Region. These geohydrologic features are shown in Figure II-11, showing a generalized cross-sections for the San Joaquin River Region. Figure II-12 shows the approximate distribution of the Corcoran Clay in the San Joaquin River Region and the location of the generalized cross section. Other clay layers are present above and below the Corcoran Clay and may have local impacts on groundwater conditions.

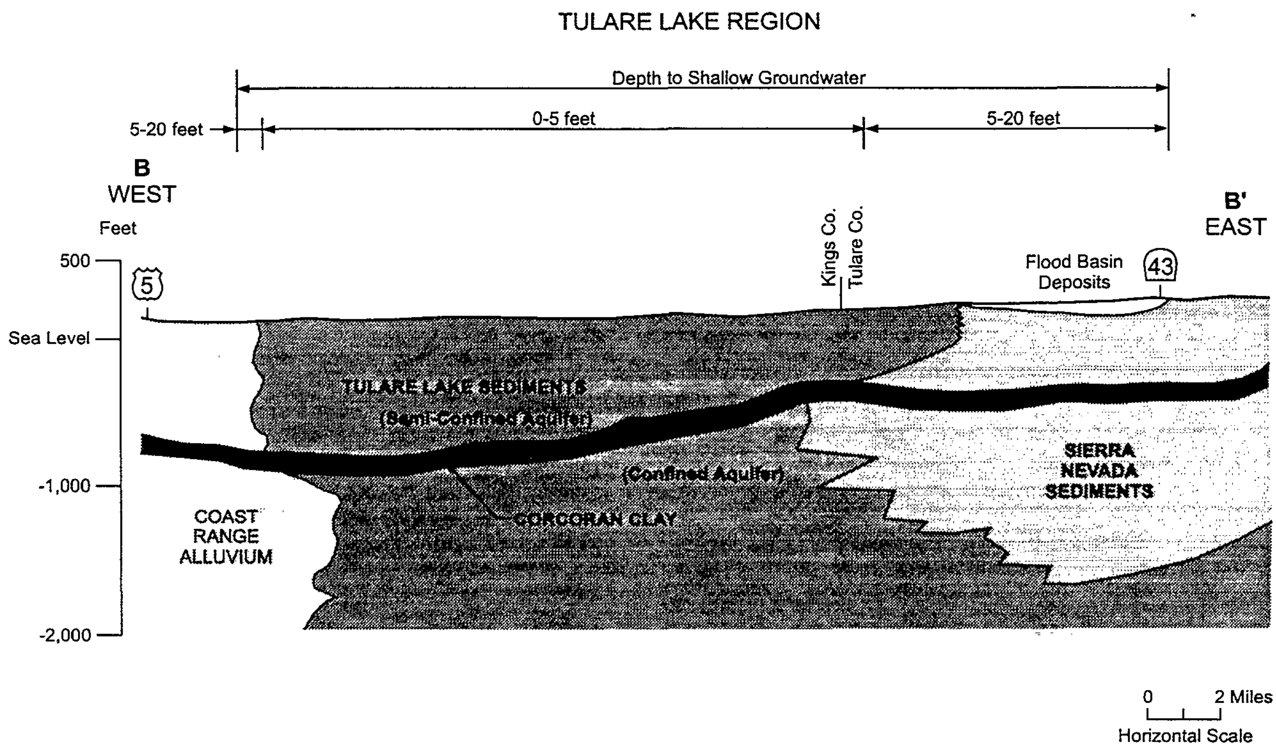
The Corcoran Clay divides the groundwater system into two major aquifers: a confined aquifer below the clay layer and a semi-confined aquifer above the layer (Williamson et al., 1989). Semi-confined conditions are defined by the USGS as (Muir, 1977):

> "...movement of groundwater is restricted sufficiently to cause differences in head between different depth zones of the aquifer during periods of heavy pumping; but during periods of little draft the water levels recover to a level coincident with the water table."

The semi-confined aquifer can be divided into three geohydrologic units based on the source of the sediment: Coast Range alluvium, Sierra Nevada sediments, and flood basin deposit. The Coast Range alluvial deposits are derived largely from the erosion of marine rocks from the Coast Range. These deposits are thickest along the western edge of the valley and taper off to the east as they approach the center of the valley floor. These sediments contain a large proportion of silt and clay, are high in salts, and contain elevated concentrations of selenium and other trace elements. The Sierra Nevada sediments on the eastern side of the region are derived primarily from granitic rock. These deposits make up most of the total thickness of sediments along the valley axis and gradually thin to the west until pinching out near the western boundary. These sediments are relatively permeable with hydraulic conductivities three times that of the Coast Range deposits (Belitz et al., 1993). The flood basin deposits are relatively thin and, in geologic terms, have been created in recent time. These deposits occur along the center of the valley floor and are generally only 5 to 35 feet thick (Westlands Water District, 1995).

Recharge to the semi-confined upper aquifer generally occurs from stream seepage, deep percolation of rainfall, and subsurface inflow along basin boundaries. As agricultural practices expanded in the region, recharge was augmented with deep percolation of applied agricultural water and seepage from the distribution systems used to convey this water. Recharge of the lower confined aquifer consists of subsurface inflow from the valley floor and foothill areas to the east of the eastern boundary of the Corcoran Clay Member. Present information indicates

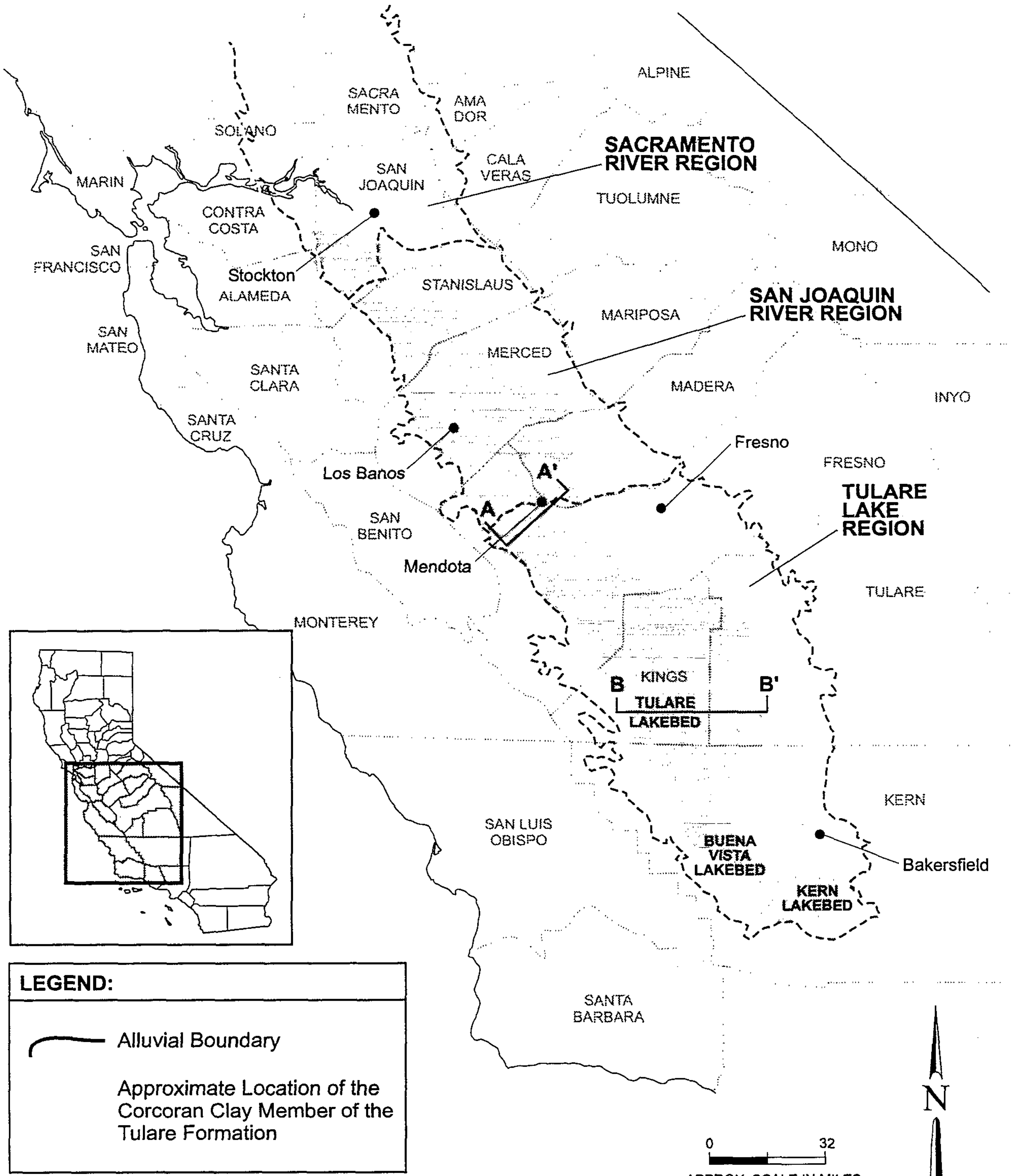




Source: Adapted from SJVDP, 1990.

FIGURE II-11

GENERALIZED GEOHYDROLOGICAL CROSS-SECTIONS IN THE SAN JOAQUIN RIVER AND TULARE LAKE REGIONS (LOCATIONS SHOWN IN FIGURE II-12)



Source: Adapted from Ireland, 1986.

FIGURE II-12

APPROXIMATE BOUNDARY OF THE CORCORAN CLAY MEMBER

that the clay layers, including the Corcoran Clay, are not continuous in some areas, and some seepage from the semi-confined aquifer above does occur through the confining layer.

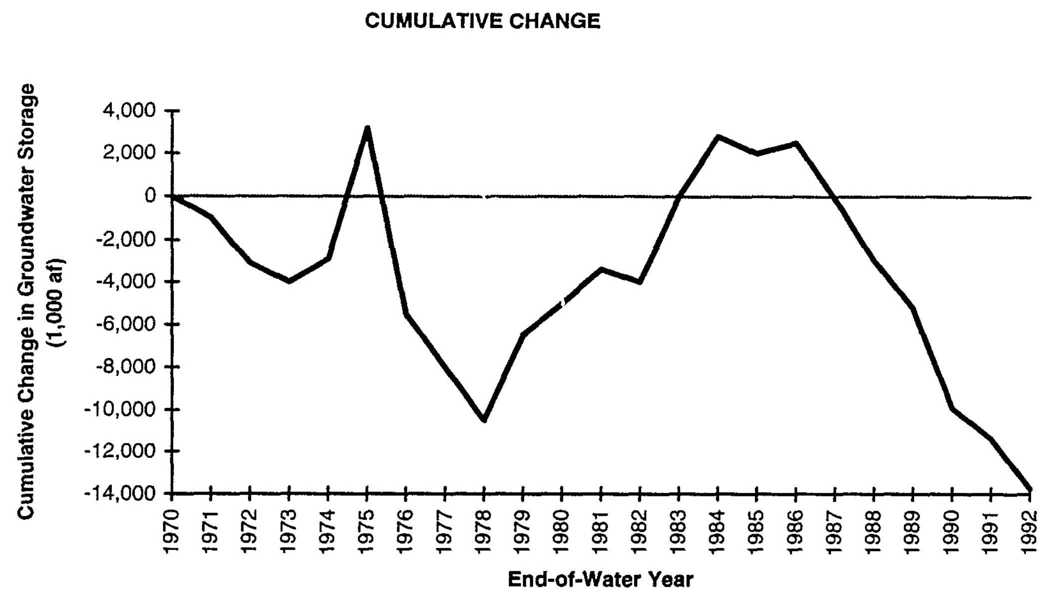
Historically, the interaction of groundwater and surface water resulted in net gains to the streams. This condition existed on a regional basis through about the mid 1950s. Since that time groundwater level declines have resulted in some stream reaches losing flow through seepage to the groundwater systems below. Where the hydraulic connection have been maintained, the amount of seepage has varied as groundwater levels and streamflows have fluctuated. Areas in the San Joaquin River Region where these dynamics have changed include the eastern San Joaquin and Merced counties, and western Madera County, as well as other local areas. Similar to the Sacramento River Region, the largest stream losses have occurred during the drought periods of 1976 to 1977 and 1987 to 1992.

During pre-development conditions, groundwater in the San Joaquin River Region flowed from the valley flanks to the axis, then north toward the Delta. Large-scale groundwater development during the 1960s and 1970s, combined with the introduction of imported surface water supplies, have modified the natural groundwater flow pattern. The groundwater pumping and recharge from imported irrigation water has resulted in a change in regional flow patterns. Flow largely occurs from areas of recharge towards areas of lower groundwater levels due to groundwater pumping (Bertoldi et at., 1991). The vertical movement of water in the aquifer has been altered in this region as a result of thousands of wells constructed with perforation above and below the confining unit (Corcoran Clay Member), where present, providing a direct hydraulic connection (Bertoldi et al., 1991). This may have been partially offset by a decrease in vertical flow resulting from the inelastic compaction of fine-grained materials within the aquifer system.

Groundwater Storage and Production

In DWR's Bulletin 160-93 usable storage capacity for the San Joaquin River Region was estimated to be approximately 24 million acre-feet (DWR, 1994). As in the Sacramento River Region, there have been numerous attempts to estimate the safe yield of the San Joaquin River Region. The most recent estimate, made by DWR, is approximately 3.3 million acre-feet of perennial yield (DWR, 1994). This perennial yield is directly dependent upon the amount of recharge received by the groundwater basin, which may be different in the future than it has been in the past.

The change in groundwater storage from 1970 to 1992 for the San Joaquin River and Tulare Lake Regions combined is shown in Figure II-13. Relative to 1970, groundwater storage in the San Joaquin Valley basin during the 1970s reached a low point in 1978, a result of the 1976 to 1977 drought period. By the early 1980s, groundwater storage returned to pre-drought conditions. Groundwater storage declines returned during the 1987-1992 drought, reaching a low for the 1970 to 1992 period at the end of the drought in 1992. At the end of the 1990 water year, the fourth year of the six-year drought, groundwater storage was similar to 1978 conditions, the third year following the onset of the two-year drought in 1976-1977. The extremely critical nature of the two-year drought resulted in a greater rate of decline in comparison to the six-year drought. However, the duration of the six-year drought resulted in continued declines in groundwater storage in 1991 and 1992 to levels lower than the previous low in 1978 during this 23-year period. These groundwater storage fluctuations shown here for the San Joaquin Valley basin are



SOURCE:
DWR, 1994

FIGURE II-13
HISTORICAL CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR THE SAN JOAQUIN RIVER AND TULARE LAKE REGIONS (1970-1992)

a reasonable representation of the area-wide fluctuations occurring in the San Joaquin River Region.

Figure II-14 shows the relationship between historical groundwater pumping and irrigated agricultural acreage in the San Joaquin River Region from 1922 to 1980 (the source of this data is discussed in the Groundwater Resources of the Sacramento River Region, Groundwater Storage and Production section). Groundwater pumping ranged from 1.6 million acre-feet in 1922 to 4.7 million acre-feet in 1977. Groundwater pumping has been rising steadily through the 1970s, and has varied greatly from year to year depending on hydrologic conditions. This variation is demonstrated in Figure II-14 which shows the largest year-to-year fluctuation during the 1976 to 1977 drought period. Immediately following the drought, hydrologic conditions for the years 1978, 1979, 1970, characterized as wet, above normal, and wet, respectively, were largely responsible for the reduced pumping following the drought period.

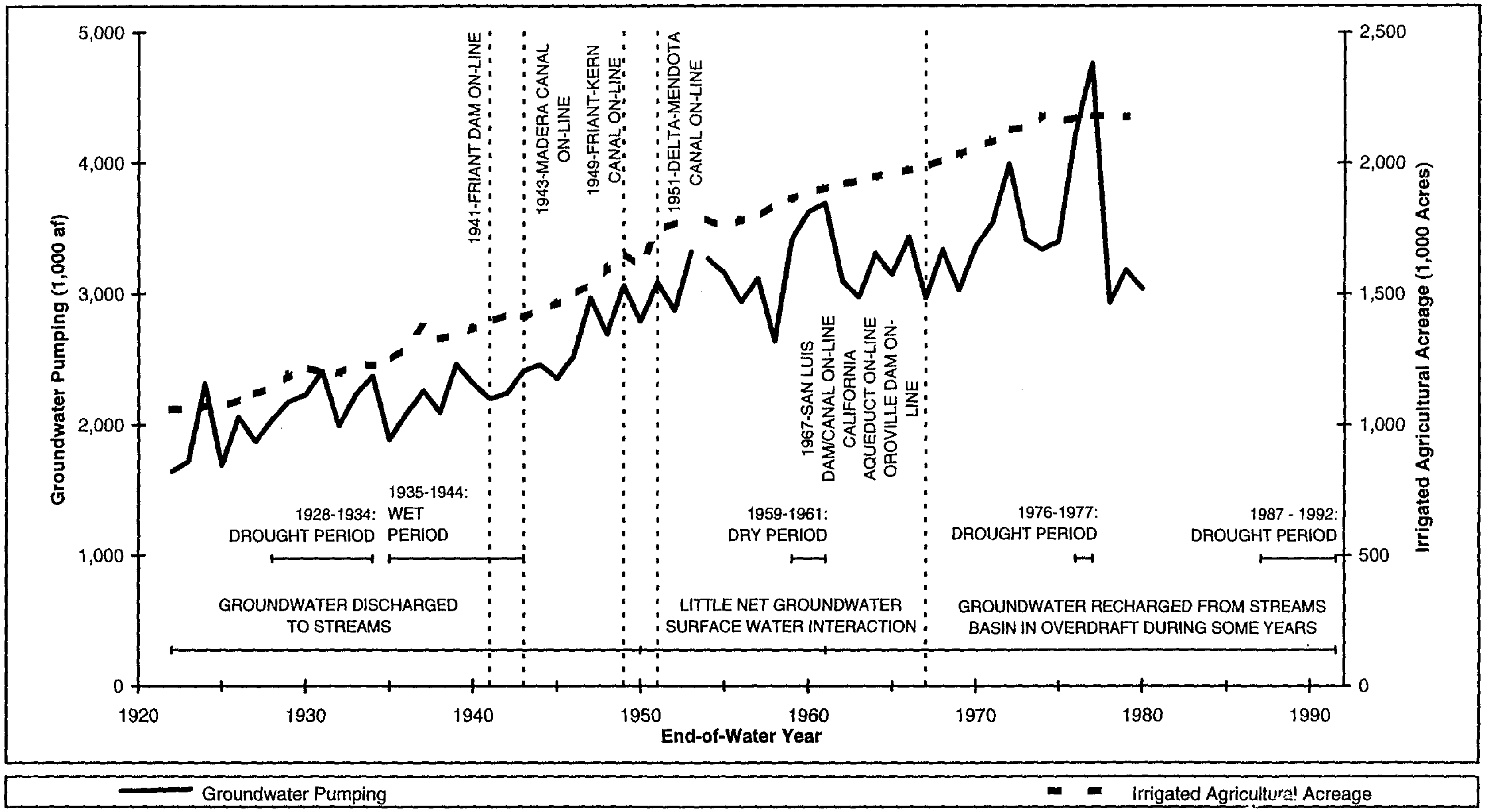
As in to the Sacramento River Region, urban growth during the 1980s has contributed to an increase in groundwater pumping. In addition, increases in groundwater pumping in the late 1980s and early 1990s occurred in response to reduced surface water deliveries to Central Valley water users due to the imposition of environmental requirements on the operation of surface water facilities, and critically dry hydrologic conditions during the 1987 to 1992 drought period (DWR, 1994).

The DWR estimated recent groundwater pumping for 1990 conditions (normalized) in the San Joaquin River Region to be 3.5 million acre-feet. This exceeds the estimated perennial yield by approximately 200 taf. All of the subbasins within the San Joaquin River Region experienced some overdraft (DWR, 1994).

Groundwater Levels

Expansion of agricultural practices between 1920 and 1950 caused declines in groundwater levels in many areas of the San Joaquin River Region. Along the east side of the region declines have ranged between 40 and 80 feet since predevelopment conditions (1860) (Williamson et al., 1989). Groundwater levels declined substantially in the Madera County area which depends heavily on groundwater for irrigation (Williamson et al., 1989).

Declines began occurring in the 1940s along the west side of the San Joaquin River Region, dropping more than 30 feet by 1960. In the confined aquifer of northwestern Fresno County, groundwater levels were recorded as ranging from 200 feet below sea level to sea level in spring 1960 (reported by DWR). By spring 1970, groundwater levels (reported by DWR) in this same area were recorded as ranging from 200 feet to 100 feet below sea level, a drop of as much as 100 feet. Groundwater levels in central San Joaquin County reached 50 feet below sea level by spring 1970 causing saline groundwater intrusion problems for the city of Stockton. By spring 1980, confined aquifer groundwater levels (reported by DWR) along northwestern Fresno County and western Merced County increased up to 100 feet Groundwater levels in the semi-confined aquifer between spring 1970 and spring 1980 declined in response to 1976-1977 drought conditions and recovered to near pre-drought levels by 1980.



NOTE:

Data available from 1922 to 1980. Data developed as part of the Central Valley Ground-Surface Water Model (Reclamation et al., 1990).

SOURCE:

Reclamation et al., 1990.

FIGURE II-14
HISTORICAL GROUNDWATER PUMPING AND IRRIGATED AGRICULTURAL ACREAGE FOR THE SAN JOAQUIN RIVER REGION

The 1987-1992 drought resulted in substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley (Westlands Water District, 1995). Recent groundwater conditions, observed following the drought, for spring 1993 are shown in Figure II-15. Depression areas resulting from groundwater withdrawals are indicated along the east side of the San Joaquin River Region in Merced and Madera counties and are less than 50 feet above sea level. These groundwater levels are indicative of depleted conditions due to regional groundwater withdrawals resulting from the 1987-1992 drought period. This is consistent with observed storage recovery time which may span several years. For example, recovery to pre-drought storage conditions took more than five years following the 1976-1977 drought (see Figure II-13). See the groundwater levels discussion for the Tulare Lake Region for additional information.

Land Subsidence

Beginning in the 1920s, the use of groundwater for irrigation of crops began to increase rapidly until the mid-1960s in the San Joaquin Valley. As a result of this heavy pumping, groundwater level declines have caused land subsidence throughout the valley. Land subsidence is a significant problem in the San Joaquin River and Tulare Lake regions. From 1920 to 1970, almost 5,200 square miles of irrigated land in the San Joaquin River and Tulare Lake regions registered at least 1 foot of land subsidence (Ireland, 1986). By the mid 1970s the use of imported surface water in the western and southern portions of San Joaquin Valley essentially eliminated new land subsidence. During the 1976 to 1977 drought land subsidence was again observed in areas previously affected due to renewed high groundwater pumping rates. After nearly two decades of little or no land subsidence, significant land subsidence has been recently detected in the San Joaquin Valley due to increased groundwater pumping during the 1987-1992 drought. Land subsidence occurring between 1984 and 1996 was reported along the Delta-Mendota Canal. Two locations of note are: (1) near Mendota Pool where 1.3 feet of land subsidence was measured, and (2) approximately 25 miles northeast of Mendota Pool where 2.0 feet of land subsidence was measured (Central California Irrigation District, 1996). Measured land subsidence by DWR between 1990 and 1995 of up to 2.0 feet was reported along the California Aqueduct in Westlands Irrigation District (Dudley, 1995).

Land subsidence in the San Joaquin Valley has occurred mostly in areas that are confined by the Corcoran Clay, where pressure changes caused by groundwater pumping promote greater compressive stress than in the unconfined zone (DWR, 1977). (Additional discussion of land subsidence processes is provided in Attachment C of the CVGSM Methodology and Modeling Technical Appendix.) Figure II-8 shows 1926 to 1970 land subsidence contours for the 2,600 square-mile Los Banos-Kettleman City area. This area, the largest of the three land subsidence areas in the San Joaquin River and Tulare Lake regions, extends from Merced County to Kings County but is mostly located within western Fresno County. The maximum land subsidence levels recorded in the Central Valley occurred in this area. In parts of northwestern Fresno County, land subsidence levels of as great as 30 feet have been measured (Ireland et al., 1982).

Because of the slow drainage of the fine-grained deposits, subsidence at a particular time is more closely related to past water-level change than to current change. For example, in the San Joaquin Valley, groundwater withdrawals increased greatly until large imports of surface water

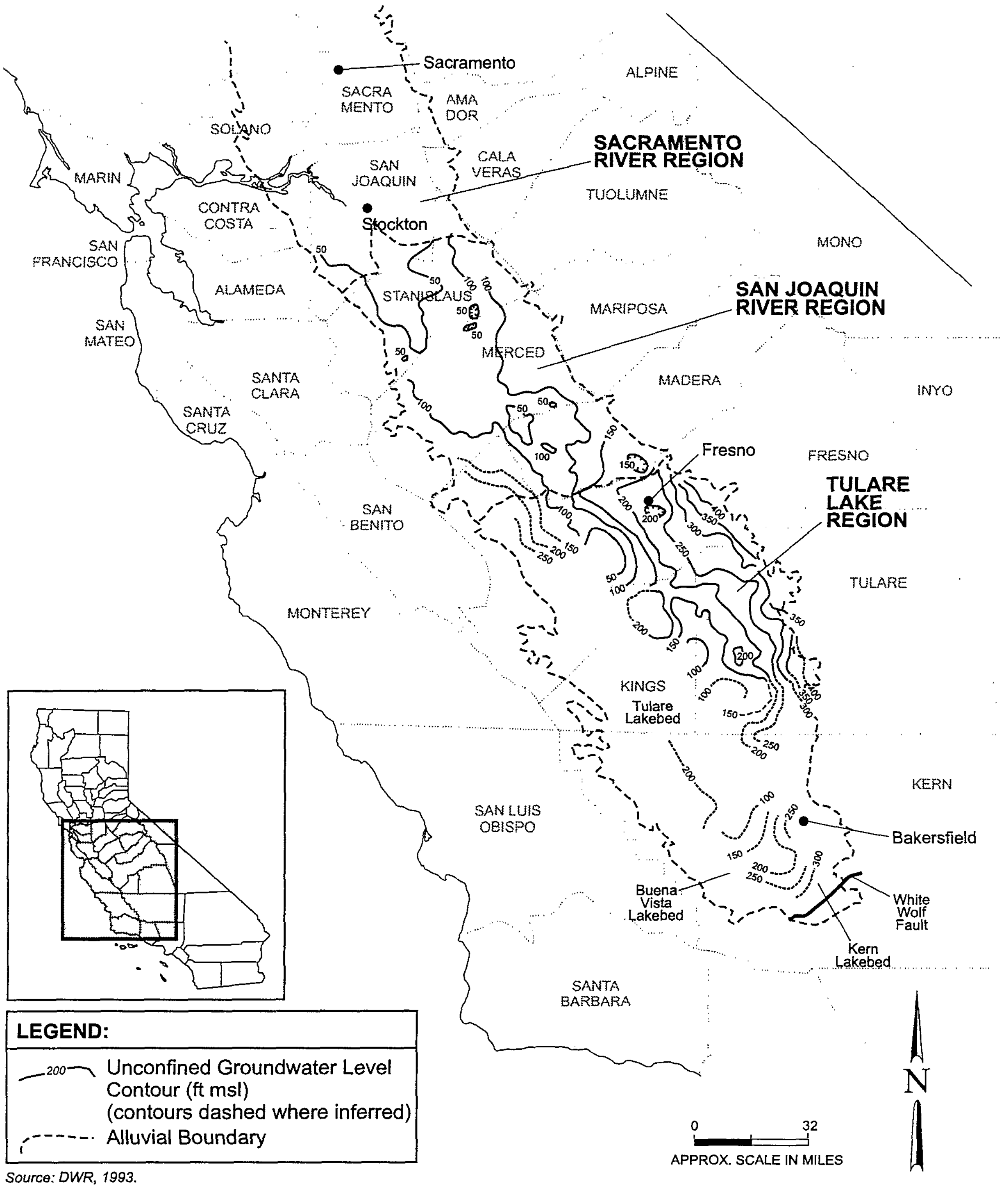


FIGURE II-15

GROUNDWATER ELEVATIONS IN THE SAN JOAQUIN VALLEY, SPRING 1993

through various canals occurred, but even though water levels in the area started to rise, the rate of subsidence began to decrease three years later.

Groundwater Quality

Groundwater quality conditions in the San Joaquin River Region varies throughout the area. Groundwater quality parameters included in this technical appendix are listed in Table II-1 and are discussed below for the San Joaquin River Region. Table II-1 also lists the sources and reasons for concerns associated with these parameters. Only those parameters that are associated with regional problems are discussed here. Site-specific groundwater quality issues with unique conditions would not likely be affected by regional changes represented in the CVPIA PEIS. However, any future site-specific studies associated with the CVPIA may require more detailed assessment of these local issues.

Total Dissolved Solids. TDS concentrations vary considerably in the San Joaquin River and Tulare Lake Region, depending upon the groundwater zone. Figure II-9 is a composite of data from existing wells with a wide variety of depths and screen lengths, and is a representation of likely TDS concentrations found in groundwater zones most commonly used. The map does not show vertical variations in TDS. Additional information regarding the shallow groundwater zone associated with the west side of the San Joaquin River Region is provided in the subsequent Agricultural Subsurface Drainage section.

Referring to Figure II-9, TDS concentrations in groundwater along the east side of the San Joaquin Valley are lower in comparison to concentrations in the west side of the San Joaquin River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates in the Sierra Nevada, and the predominant regional groundwater flow pattern. In the center and on the east side, TDS concentrations generally do not exceed 500 mg/l. On the west side, TDS concentrations are generally greater than 500 mg/l, and in excess of 2,000 mg/l along portions of the western margin of the valley (Bertoldi et al., 1991). The concentrations in excess of 2,000 mg/l commonly occur above the Corcoran Clay layer.

Impaired municipal use of groundwater as drinking water supply due to elevated TDS concentrations occurs at several locations throughout the San Joaquin River Region (SWRCB, 1991).

Boron. High boron concentrations occur in the northwestern part of the San Joaquin River Region from the northernmost edge of the region to the southernmost edge of the region (Bertoldi et al., 1991). Agricultural use of groundwater is impaired due to elevated boron concentrations in eastern Stanislaus and Merced counties (SWRCB, 1991).

Nitrates. In the San Joaquin River Region, a large area within the northern San Joaquin County (between Lodi and Stockton) contain NO_3-N concentrations in groundwater exceeding 5 mg/l (Bertoldi et al., 1991). Municipal use of groundwater as a drinking water supply is also impaired due to elevated nitrate concentrations in the Tracy, Modesto-Turlock, Merced, and Madera areas (SWRCB, 1991).

Arsenic. In the San Joaquin River Region, municipal use of groundwater as a drinking water supply is impaired due to elevated arsenic concentrations in eastern Contra Costa, Stanislaus and Merced counties, and western San Joaquin County (SWRCB, 1991).

Selenium. Selenium was found to be responsible for mutations of migratory birds in the Kesterson National Wildlife Refuge. High selenium concentrations in soils of the west side of the San Joaquin River Region have raised considerable concern because of their potential to leach from the soil by subsurface irrigation return flow into the groundwater and into receiving surface waters (Bertoldi et al., 1991). Although selenium is currently regulated by federal primary drinking water standards at an MCL of 50 μg/l, USEPA recently established chronic and acute toxicity criteria of 5 and 20 μg/l, respectively, for the protection of wildlife and aquatic organisms. The SWRCB, Central Valley Region, has established monthly mean and daily maximum selenium objectives of 5 and 12 μg/l, respectively, for the San Joaquin River from the mouth of the Merced River to Vernalis and 10 and 26 μg/l from Sack Dam to the mouth of the Merced River (SWRCB, Central Valley Region, 1992).

Selenium occurs naturally in soils and groundwater on the west side of the San Joaquin River Region. Selenium concentrations in shallow groundwater along the west side of the region have been highest in the central and southern area south of Los Banos and Mendota (median concentrations of 10,000 to 11,000 μg/l) (Bertoldi et al., 1991).

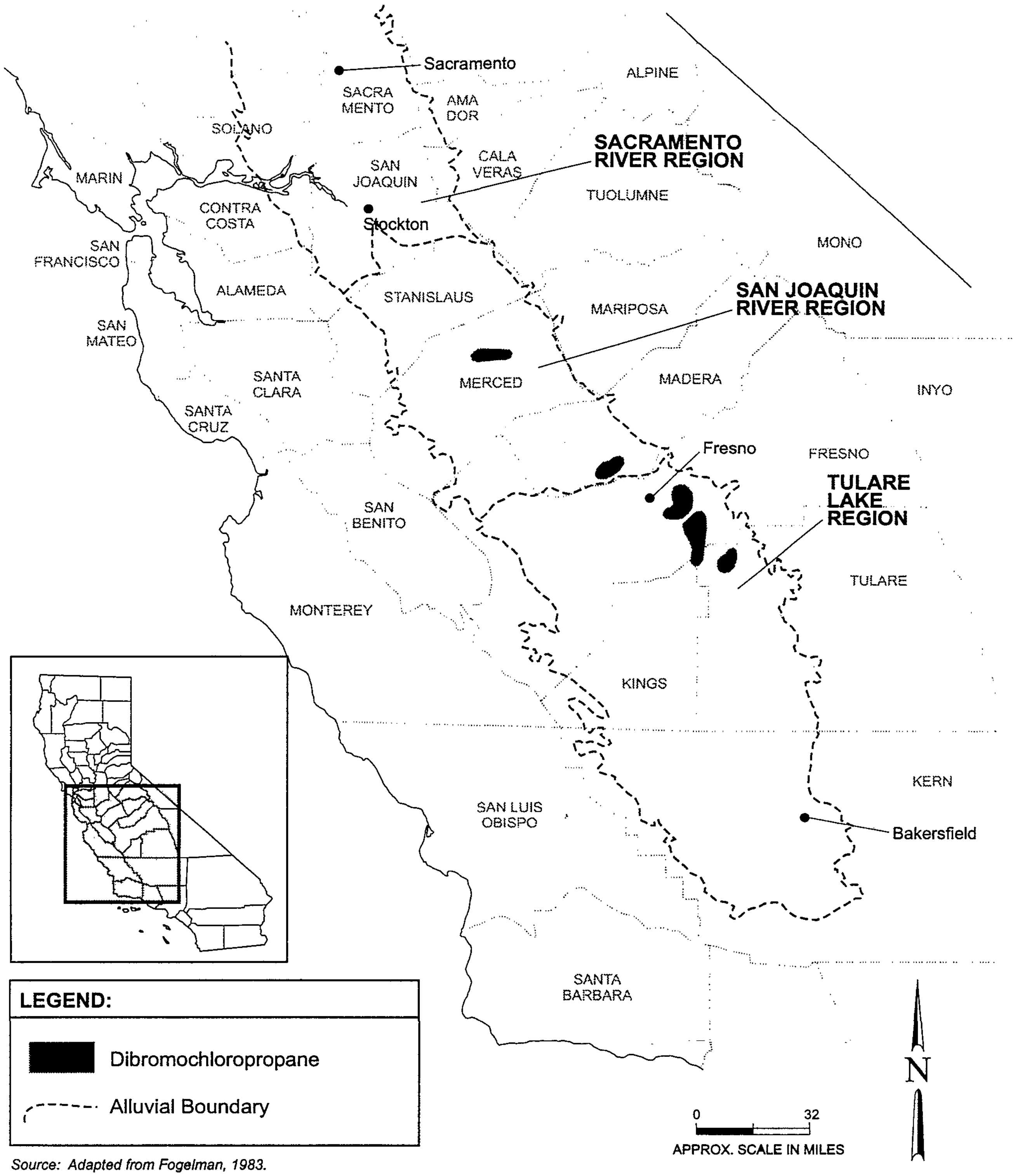
The Draft EIS for the San Luis Unit Drainage Program reports minimum and maximum selenium concentrations of less than 1 and 21 μg/l, respectively, above the mouth of the Merced River and 0.1 and 23 μg/l below. Use of groundwater to support aquatic species is impaired due to elevated selenium concentrations between Los Banos and Mendota in the western San Joaquin River Region (SWRCB, 1991).

Dibromochloropropane. DBCP has been detected in many groundwater wells in the San Joaquin River Region. Figure II-16 shows areas of groundwater contamination by DBCP. Municipal use of groundwater as drinking water supply is impaired due to elevated DBCP concentrations in groundwater near several cities within the San Joaquin River Region, including Chowchilla, Madera, Merced, and the Modesto-Turlock area (SWRCB, 1991).

Agricultural Subsurface Drainage

Inadequate drainage and accumulating salts have been persistent problems for irrigated agriculture along the west side and in parts of the east side of the San Joaquin River Region for more than a century. The most extensive drainage problems exist on the west side of the San Joaquin River and Tulare Lake regions. A detailed time line for these west side drainage problems is presented in Table II-2.

The soils on the west side of the region are derived from marine sediments and are high in salts and trace elements. Irrigation of these soils has mobilized these compounds and facilitated their movement into the shallow groundwater. Much of this irrigation has been with imported water, resulting in rising groundwater and increasing soil salinity. Where agricultural drains have been installed to control rising water tables, drainage water frequently contains high concentrations of salts and trace elements (SJVDP, 1990).



Source: Adapted from Fogelman, 1983.

FIGURE II-16

AREAS OF ELEVATED DBCP LEVELS IN GROUNDWATER OF THE SAN JOAQUIN VALLEY

TABLE II-2

EVENTS AFFECTING DRAINAGE CONDITIONS ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

Year	Event
1870s	Widespread planting of grain on the western side of the San Joaquin Valley. Crops were irrigated with water from the San Joaquin and King rivers. Poor natural drainage, rising groundwater, and increasing soil salinity resulted in the removal or abandonment of farm land in production.
1900-1950	Heavy pumping of groundwater resulted in overdrafts and widespread land subsidence.
1951	CVP water transported through the Delta-Mendota Canal to irrigate 600,000 acres of land in the northern San Joaquin Valley. This water primarily replaced and supplemented San Joaquin River water that was diverted at Friant Dam to the southern San Joaquin Valley.
1960	State Water Project (SWP) authorized. San Luis Unit of the CVP authorized which mandated construction of an interceptor drain to collect irrigation drainage water and transport it to the Delta. Reclamation's feasibility report for the San Luis Unit described the drain as an earthen ditch that would drain 96,000 acres.
1962	Reclamation changed plans for the drain to a concrete-lined canal to drain 300,000 acres.
1964	Reclamation added a regulating reservoir to the drain plans to temporarily retain drainage.
1965	Concerns were raised about the potential effects of the discharge of untreated agricultural drainage water in the Delta and San Francisco Bay. A rider was added to CVP appropriations act by Congress in 1965 that required the final point of discharge of the interceptor drain for the San Luis Unit to conform with water quality standards set by California and the USEPA.
1968	CVP's San Luis Unit and the SWP began delivering water to approximately 1,000,000 acres of agricultural lands in southern San Joaquin Valley.
	Construction of San Luis Drain began.
	Kesterson Reservoir became part of a new national wildlife refuge managed jointly by Reclamation and the U.S. Fish and Wildlife Service.
mid 1970	Reclamation decided to use the drainage reservoir to store and evaporate drainage water until the drainage canal to the Delta was completed.
1975	85 miles of the main drain, 120 miles of collector drains, and the first phase of Kesterson Reservoir completed.
	Budget and environmental concerns halt work on the reservoir and drain.
	Reclamation, DWR, and SWRCB formed the San Joaquin Valley Interagency Drain Program to find a solution to valley drainage problems. This group's recommendation was to complete the drain to a discharge point in the Delta near Chipps Island.
1981	Reclamation began a special study to fulfill requirements for a discharge permit from the SWRCB.
1983	Selenium poisoning identified as the probable cause of deformities and mortalities of migratory water fowl at Kesterson Reservoir.
1984	The SJVDP was established as a joint federal and state effort to investigate drainage and related problems and identify possible solutions.
1985	The Secretary of the Interior halted the discharge of subsurface drainage water to Kesterson.
1986	The feeder drains to the San Luis Drain and reservoir were plugged.
1988	Kesterson Reservoir was closed. The vegetation has been plowed under and low-lying areas were filled.
	Contamination-related problems similar to Kesterson were appearing in parts of the Tulare Lake Region. Wildlife deformities and mortalities had been observed at several agricultural drainage evaporation ponds.
1990	SJVDP submits final report.

SOURCE:
SJVDP, 1990.

The area of subsurface drainage problems extends along the western side of the San Joaquin River and Tulare Lake Regions from the Delta on the north to the Tehachapi Mountains south of Bakersfield. In some portions of the San Joaquin River Region natural drainage conditions are inadequate to remove the quantities of deep percolation that accrue to the water table. Therefore, groundwater levels often encroach on the root zone of agricultural crops, and subsurface drainage must be supplemented by constructed facilities for irrigation to be sustained. The area and depth of shallow groundwater for 1987 are shown in Figure II-17. The term "shallow groundwater" is referred to here as the highest zone of saturation down to a depth of approximately 20 feet.

Few wells pump from this shallow groundwater zone because of high salinity concentrations. The term "salinity" refers to the salt content of solutions containing dissolved mineral salts. Salinity is commonly measured as either TDS in parts per million (ppm) or electrical conductivity (EC) in microsiemens per centimeter (μS/cm). Salinity levels in shallow groundwater in the San Joaquin River Region range from 2,500 to 5,000 μS/cm as shown in Figure II-18, and are as high as 5,000 to 10,000 μS/cm.

Toxic and potentially toxic trace elements in some soil and shallow groundwater on the western side of the San Joaquin River and Tulare Lake regions are also of concern. These trace elements greatly complicate the disposal of subsurface drainage waters. Elements of primary concern are selenium, boron, molybdenum, and arsenic. Selenium is of greatest concern due to the wide distribution and known toxicity of selenium to aquatic animals and water fowl. Figure II-19 shows concentrations of selenium in shallow groundwater. Figure II-20 shows problem areas for boron, molybdenum, and arsenic.

Seepage and Waterlogging

In the lower reaches of the San Joaquin River and in the vicinity of its confluence with major tributaries, high periodic streamflows and local flooding combined with high groundwater levels have resulted in seepage-induced waterlogging damage to low-lying farm land. In the western portion of the Stanislaus River watershed, groundwater pumping has historically been used for control of high groundwater levels and seepage-induced waterlogging conditions. Along the San Joaquin River from the confluence with the Tuolumne River through the South Delta, flood control operations in conjunction with spring pulse flow requirements has recently contributed to seepage-induced waterlogging damage to low-lying farm land, a result of streamflow seepage into adjacent shallow groundwater aquifers. The seepage-induced waterlogging places neighboring crops and farm land at risk and prevents cultivation of the land until the summer months, placing the annual crop production at risk. Concern has been raised that San Joaquin River flows in excess of 16,000 cubic fee per second (cfs) at Vernalis can result in seepage-induced waterlogging damage of adjacent low-lying farm land in the south Sacramento-San Joaquin Delta area (Hildebrand, 1996).

GROUNDWATER RESOURCES OF THE TULARE LAKE REGION

The southern part of the San Joaquin Valley basin, referred to here as the Tulare Lake Region (Figure II-1), is a basin of interior drainage. Details of the San Joaquin Valley basin were discussed earlier under Groundwater Resources of the San Joaquin River Region. Additional detail pertinent to the Tulare Lake Region follow.

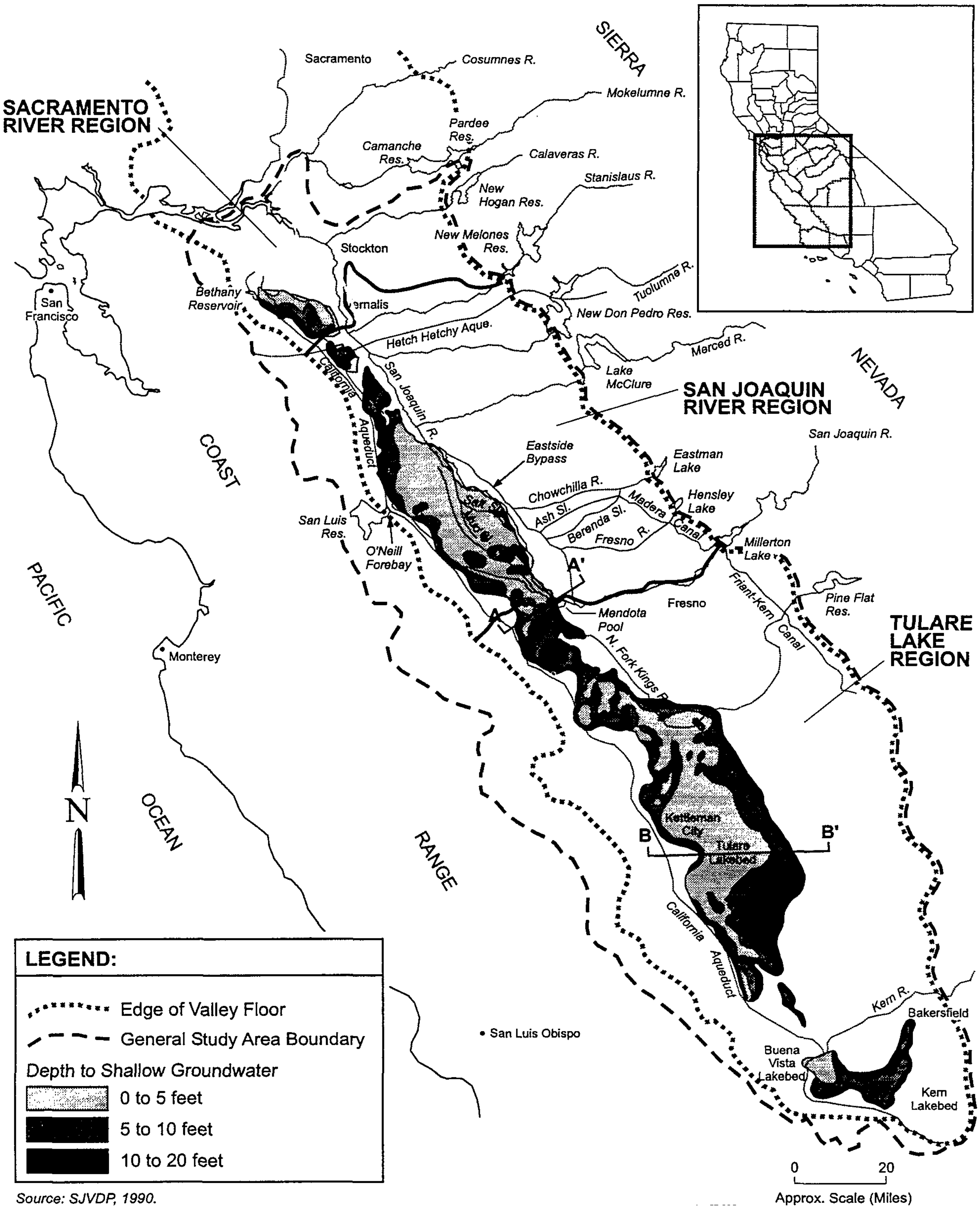
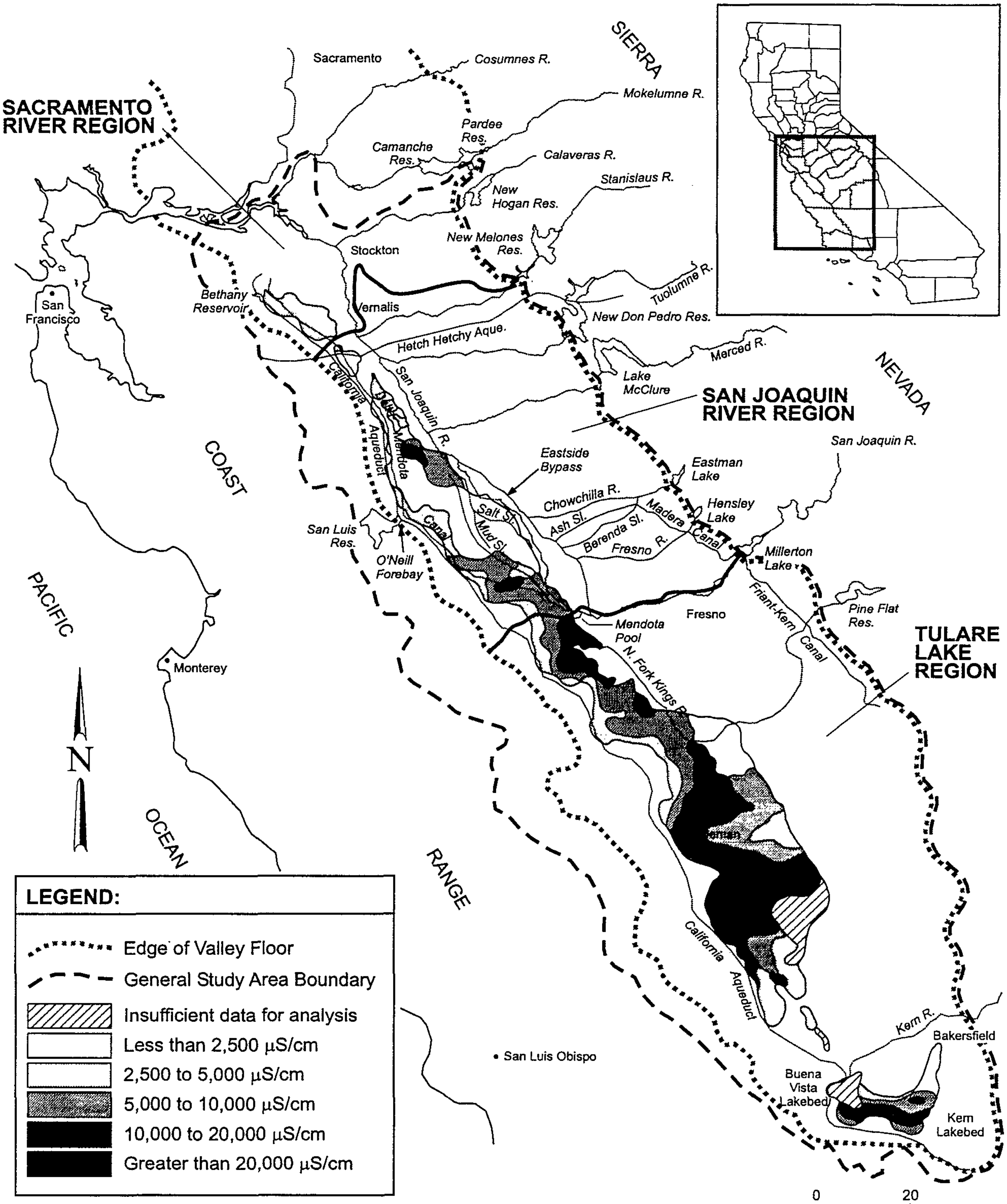


FIGURE II-17

AREAS OF SHALLOW GROUNDWATER, 1987



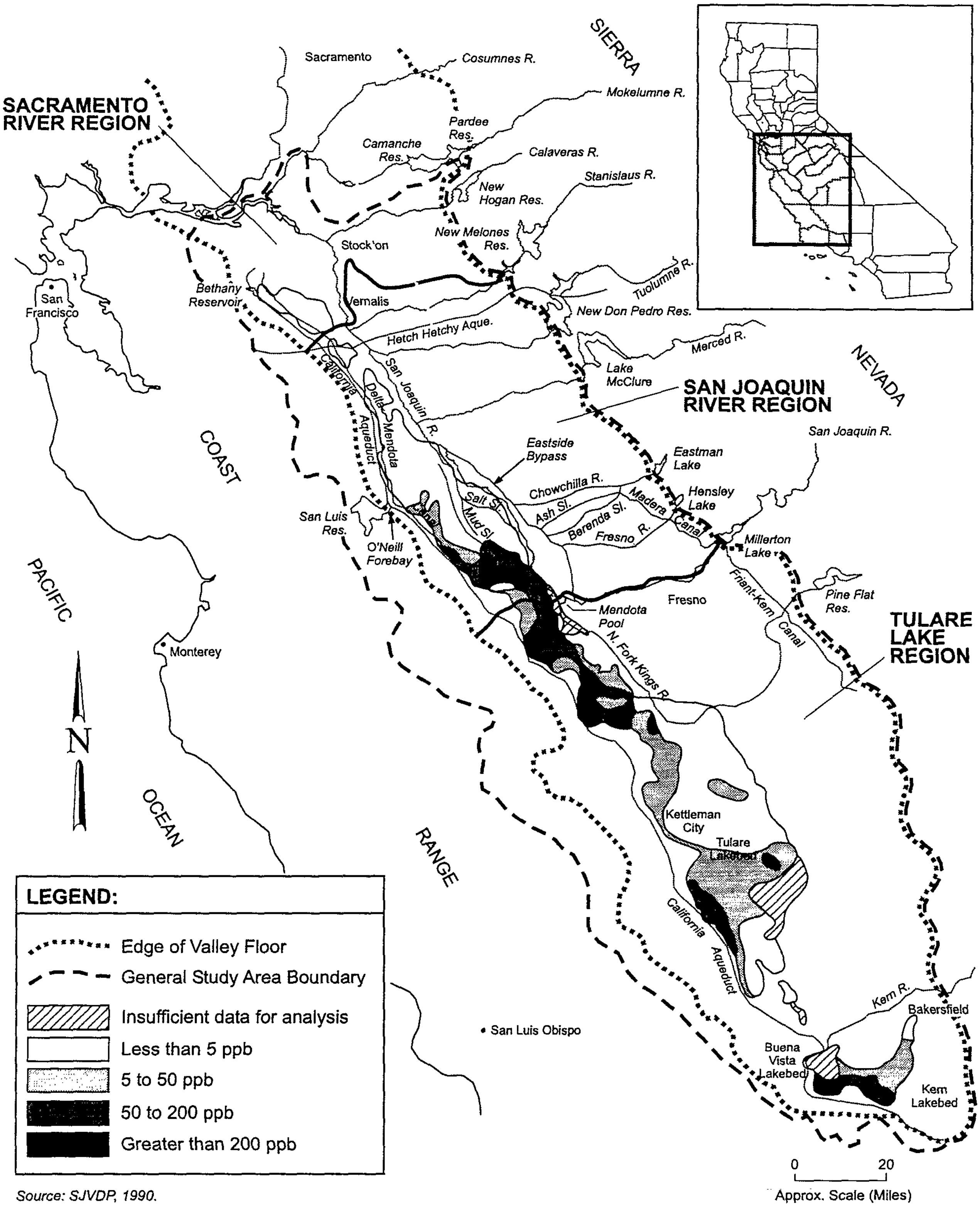
Source: SJVDP, 1990.

FIGURE II-18

SALINITY IN SHALLOW GROUNDWATER, SAMPLED BETWEEN 1984 AND 1989

C—080389

C-080391



Source: SJVDP, 1990.

FIGURE II-19

SELENIUM CONCENTRATIONS IN SHALLOW GROUNDWATER, SAMPLED BETWEEN 1984 AND 1989

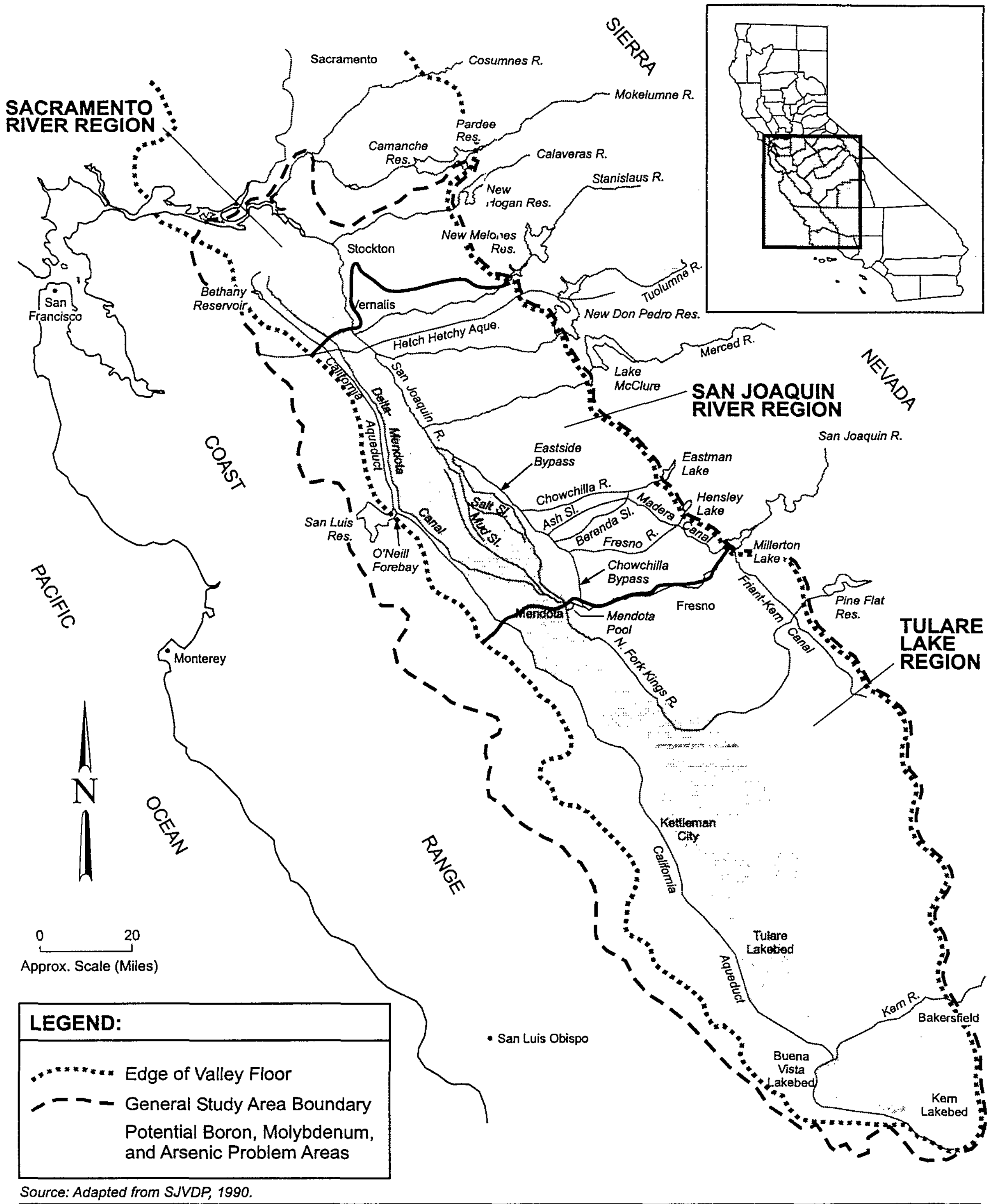


FIGURE II-20

POTENTIAL BORON, MOLYBDENUM, AND ARSENIC PROBLEM AREAS IN SHALLOW GROUNDWATER OF THE SAN JOAQUIN VALLEY

C-080391

C-080393

DWR-defined subbasins in the southern half of the San Joaquin Valley basin, lying within the Tulare Lake Region, include the Kings, Tulare Lake, Kaweah, Tule, Westside, Pleasant Valley, and Kern subbasins (DWR, 1994).

Hydrogeology

The Tulare Lake Region contains the same geohydrologic features as the San Joaquin Valley basin; the Coast Range alluvium, the Sierra Nevada sediments, and the flood basin deposits, but it also contains Tulare Lake sediments in the axis of the valley. This basin is characterized by the presence of several dry lakebeds (SJVDP, 1990). The generalized geohydrologic features of the Tulare Lake Region are shown in Figure II-11. The Corcoran Clay occurs at depths of 300 to 900 feet below the land surface in the Tulare Lake Region. Figure II-12 shows the approximate distribution of the Corcoran Clay in the region.

Semi-confined aquifer conditions exist on the west side of the Tulare Lake Region above the Corcoran Clay layer, as well as to the east, where the clay is not present. This area of the aquifer consists of the same three geohydrologic units found in the San Joaquin River Region. A fourth unit, the Tulare Lake sediments, also exists in this region, and has similar characteristics to the flood basin deposits present in the San Joaquin River Region.

Recharge of the semi-confined aquifer in the Tulare Lake Region is primarily derived from seepage from streams and canals, infiltration of applied water, and subsurface inflow. Precipitation on the valley floor provides some recharge, but only in abnormally wet years. Seepage from streams and canals is highly variable depending on annual hydrologic conditions. Recharge to the lower confined aquifer takes place largely through lateral inflow from the semi-confined aquifer (discussed previously in the Hydrogeology section of the San Joaquin River Region). Present information indicates that the clay layers, including the Corcoran Clay, are not continuous in some areas, and some seepage from the semi-confined aquifer above does occur through the confining layer.

Early agricultural development (pre-1900s) in this region, together with more arid conditions than in the northern two thirds of the Central Valley, has resulted in greater groundwater level declines, which has caused a change in stream-aquifer dynamics. In the period of predevelopment, the interaction was very dynamic with water exchanged in both directions depending upon variations in hydrologic conditions. With the onset and rapid growth of the agricultural sector in the region, groundwater was heavily developed, resulting in regional groundwater level declines. Subsequently, the loss of streamflows to underlying aquifers became the prevailing condition. In some areas of severe overdraft, such in the Kings and Kern counties, complete disconnection between groundwater and overlying surface water systems has occurred. Many streams and conveyance systems are characterized as "leaky" and, in addition to conveying surface water for irrigation purposes, are also used with the intention of recharging groundwater.

Groundwater Storage and Production

In DWR's Bulletin 160-93, usable storage capacity for the Tulare Lake Region was estimated to be approximately 28 million acre-feet (DWR, 1994). As in the Sacramento River Region, there have been numerous attempts to estimate the safe yield of the Tulare Lake Region, the most recent estimate, made by DWR, is approximately 4.6 million acre-feet of perennial yield (DWR, 1994). This perennial yield is directly dependent upon the amount of recharge received by the groundwater basin, which may be different in the future than it has been in the past.

The change in groundwater storage from 1970 to 1992 for the combined San Joaquin River and Tulare Lake regions combined was discussed previously, and are presented in Figure II-13. These groundwater storage fluctuations represent regional fluctuations that likely occurred in the Tulare Lake Region.

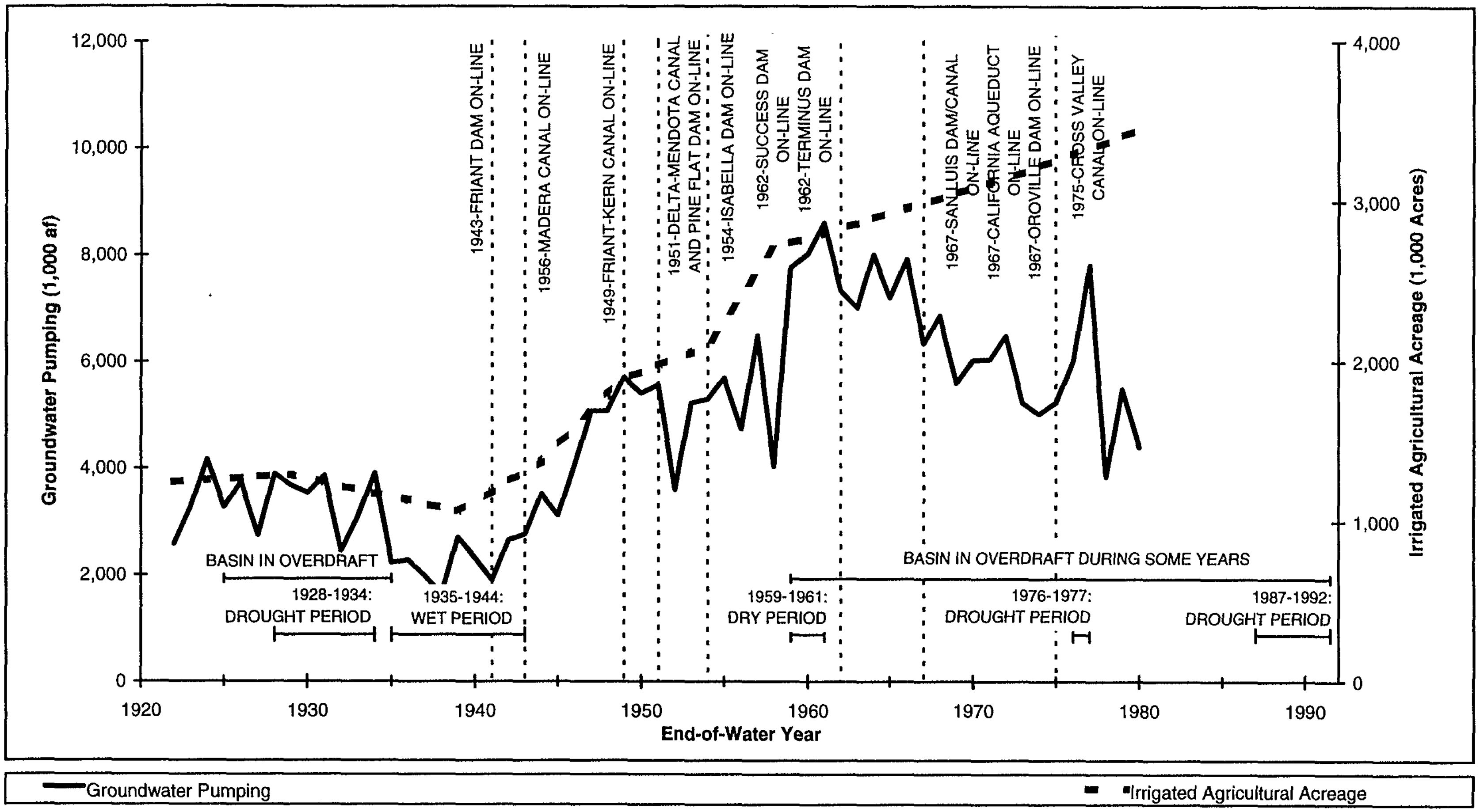
The Tulare Lake Region has extensive agricultural development since the 1800s. By 1922, more than 1.2 million acres of land were in agricultural production and groundwater was the primary source of irrigation water. Figure II-21 shows the changes in groundwater pumping and irrigated agricultural acreage for the Tulare Lake Region from 1922 to 1980 (the source of this data is discussed in the Groundwater Resources of the Sacramento River Region, Groundwater Storage and Production section). Groundwater pumping ranged from 2 million acre-feet in the 1920s and 1930s to 8 million acre-feet in the 1960s. Groundwater pumping increased steadily until 1949, at which time the Friant-Kern Canal began delivering water to the east side of the region. Groundwater pumping continued to increase through the early 1960s. During the 1960s the introduction of local surface water facilities and imports of CVP water from the San Luis Division and SWP water from the California Aqueduct were largely responsible for the reduced regional groundwater pumping. Additional CVP supplies were imported into the southern half of the region with the introduction of the Cross Valley Canal in the mid-1970s. This continued to reduce the demands on regional groundwater pumping and worked towards reducing overdraft conditions. Similar to the San Joaquin River Region, increases in groundwater pumping in the late 1980s and early 1990s occurred in response to reduced surface water deliveries to Central Valley water users due to the imposition of environmental requirements on the operation of surface water facilities, and critically dry hydrologic conditions during the 1987 to 1992 drought period.

The DWR estimated 1990 groundwater pumping for 1990 conditions (normalized) in the Tulare Lake Region to be 5.2 million acre-feet. This is higher than the estimated perennial yield by approximately 630 taf. All of the subbasins experienced some overdraft (DWR, 1994).

Groundwater Levels

Central Fresno County groundwater level declines in relatively shallow wells have been substantial, starting in the early 1940s and dropping to 50 to 100 feet through the 1980s (Williamson et al., 1989). In the southwestern corner of the Westside subbasin, area wells show large declines until the late 1960s. Beginning in 1967, groundwater level declines of more than 100 feet were followed by near full recovery due to decreases in pumping, in response to imported surface water supplies, from the San Luis Canal (Williamson et al., 1989).

Water levels in the lower confined aquifer declined by as much as 400 feet in the Westside area from pre-development to the 1960s (Williamson et al., 1989). During the 10-year period from spring 1970 (reported by DWR) to spring 1980 (reported by DWR), confined groundwater levels measured north of Tulare Lake Bed had increased by more than 100 feet in some areas.



NOTE:

Data available from 1922 to 1980. Data developed as part of the Central Valley Ground-Surface Water Model (Reclamation et al., 1990).

SOURCE:

Reclamation et al., 1990.

FIGURE II-21
HISTORICAL GROUNDWATER PUMPING AND IRRIGATED AGRICULTURAL ACREAGE FOR THE TULARE LAKE REGION

Confined groundwater levels south of Tulare Lake bed showed little change between 1970 and 1980.

Confined groundwater levels along the west side of Fresno and Merced counties increased by up to 150 feet during this same 10-year period. The spring 1988 confined groundwater levels (reported by DWR) north of Tulare Lake Bed indicate an additional rise of nearly 100 feet in some areas since the spring 1980 measurements.

During the 10-year period from spring 1970 (reported by DWR) to spring 1980 (reported by DWR), semi-confined groundwater levels generally dropped in the Tulare Lake Region. In portions of Fresno, Kings, Kern, and Tulare counties, semi-confined groundwater levels dropped as much as 50 feet since spring 1970. The semi-confined aquifer in the Tulare Lake Region showed little change between spring 1980 and spring 1988 (reported by DWR).

The 1987-1992 drought resulted in substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley (Westlands Water District, 1995). Recent semi-confined groundwater conditions, observed following the drought, for spring 1993 are shown in Figure II-15. For areas where groundwater level contours are presented, depression areas resulting from groundwater withdrawals are indicated in the mid-valley area near the center of Fresno County and also near the city of Fresno, along the county border between Tulare and Kings counties, in southwestern Kings County, and in parts of Kern County. A groundwater level high occurs in northern Kings County. See the groundwater levels discussion for the San Joaquin River Region for additional information regarding effects of the 1987-1992 drought period.

Land Subsidence

As a result of heavy pumping, groundwater levels declined by more than 300 feet in certain areas during the 1940s and 1950s. Imported surface water supplies in the 1950s and 1960s reduced reliance on groundwater and helped control the rapid rate of groundwater level decline. Groundwater level declines that occurred in many areas of the Tulare Lake Region have resulted in significant land subsidence over large areas. Significant historic land subsidence caused by excessive groundwater pumping has been observed in the Los Banos-Kettleman City area (northwestern portion of the Tulare Lake Region),the Tulare-Wasco area, and the Arvin-Maricopa.

Figure II-8 shows 1926 to 1970 land subsidence contours for the 2,600-square-mile Los Banos-Kettleman City area. This area, the largest of the three land subsidence areas in the San Joaquin River and Tulare Lake regions, extends from Merced County to Kings County but is mostly located within western Fresno County (see San Joaquin River Region section).

Tulare-Wasco area land subsidence contours for the period from 1926 through 1970 are also depicted in Figure II-8. This 1,200-square-mile area is located between Fresno and Bakersfield, lying mostly in Tulare County. More than half of the area (the area west of Highway 99) is underlain by Corcoran Clay. There are two local areas where land subsidence has exceeded 12 feet (Ireland et al., 1982).

Figure II-8 shows land subsidence contours for the Arvin-Maricopa area between 1926 and 1970. This 700-square-mile area is located 20 miles south of Bakersfield, mostly in Kern County. Two confining beds, the A clay and the C clay, underlay the area. The C clay is the more extensive of the two beds. Maximum land subsidence in the Arvin-Maricopa area exceeds 9 feet. Land subsidence in parts of the Arvin-Maricopa area has also been influenced by oil and gas withdrawal and hydrocompaction.

After nearly two decades of little or no land subsidence, significant land subsidence has been recently detected in the San Joaquin Valley due to increased groundwater pumping during the 1987-1992 drought. Land subsidence occurring between 1984 and 1996 was reported along the Delta-Mendota Canal (DMC). Two locations of note are: (1) near Mendota Pool where 1.3 feet of land subsidence was measured, and (2) approximately 25 miles northeast of Mendota Pool where 2.0 feet of land subsidence was measured (Central California Irrigation District, 1996). Measured land subsidence by DWR between 1990 and 1995 of up to 2.0 feet was reported along the California Aqueduct in Westlands Irrigation District (Dudley, 1995).

Groundwater Quality

Groundwater quality conditions in the Tulare Lake Region exhibit similar variations as occurs in the San Joaquin River Region. Groundwater quality parameters included in this technical appendix are listed in Table II-1 and are discussed below for the Tulare Lake Region. Table II-1 also lists the sources and reasons for concerns associated with these parameters. Only those parameters that are associated with regional problems are discussed here. Site-specific groundwater quality issues with unique conditions would not likely be affected by regional changes represented in the CVPIA PEIS. However, any future site-specific studies associated with the CVPIA may require more detailed assessment of these local issues.

Total Dissolved Solids. TDS concentrations very considerably in the San Joaquin River and Tulare Lake Region, depending upon the groundwater zone. Figure II-9 is a composite of data from existing wells with a wide variety of depths and screen lengths, and is a representation of likely TDS concentrations found in groundwater zones most commonly used. The map does not show vertical variations in TDS. Additional discussion regarding the shallow groundwater zone associated with the west side of the Tulare Lake Region is provided in the Groundwater Resources of the San Joaquin River Region, Agricultural Subsurface Drainage section.

Referring to Figure II-9, the TDS characteristics of the Tulare Lake Region are similar to those occurring in the San Joaquin River Region. Agricultural groundwater use is impaired due to high TDS concentrations above the Corcoran Clay in the western portion of Fresno and Kings counties (SWRCB, 1991).

Boron. In the southern portion of the Tulare Lake Region, high concentrations of boron are generally found in areas southwest to Bakersfield (greater than 3 mg/l) and southeast of Bakersfield (1 to 4 mg/l) (Bertoldi et al., 1991). Concentrations as high as 4.2 mg/l have been measured near Buttonwillow Ridge and Buena Vista Slough. Agricultural use of groundwater is impaired due to elevated boron concentrations in western Fresno and Kings counties (SWRCB, 1991).

Nitrates. Several small areas of the Tulare Lake Region contain NO_3-N concentrations in groundwater in excess of 10 mg/l. These include areas south and north of Bakersfield, around the Fresno metropolitan area, and scattered areas of the Sierra Nevada foothills in the Hanford-Visalia area. Municipal use of groundwater as drinking water supply is impaired due to elevated nitrate concentrations in numerous areas throughout the Tulare Lake Region (SWRCB, 1991).

Arsenic. Municipal use of groundwater as a drinking water supply is impaired due to elevated arsenic concentrations in southwest corner of the Tulare Lake Region (SWRCB, 1991). Agricultural use of groundwater is impaired due to elevated arsenic concentrations in the Tulare Lake Region, particularly in areas of the Kern Basin near Bakersfield (SWRCB, 1991).

Selenium. Municipal use of groundwater as a drinking water supply is impaired due to elevated selenium concentrations reported from the northwest and southeast alluvial areas near Bakersfield (SWRCB, 1991).

Use of groundwater to support aquatic species is impaired due to elevated selenium concentrations in the Tulare Lake Region near Kettleman City, and in western portions of Fresno and Kings counties (SWRCB, 1991).

Dibromochloropropane. DBCP has been detected in many groundwater wells in the Tulare Lake Region. Figure II-16 shows areas of groundwater contamination by DBCP. Municipal use of groundwater as drinking water supply is impaired due to elevated DBCP concentrations in groundwater near several cities within the Tulare Lake Region, including Visalia, Bakersfield, Fresno area, and scattered locations in southwest Tulare County (SWRCB, 1991).

Agricultural Subsurface Drainage

The subsurface drainage problems associated with the west side of the San Joaquin Valley extend from north to south in the Tulare Lake Region. Shallow groundwater levels contributing to subsurface drainage problem are shown for the Tulare Lake Region in Figure II-17. Recent reports indicate that long-term groundwater storage in these regions are increasing, further aggravating the problem (DWR, 1994). As in the San Joaquin River Region, salinity and trace elements in some soil and shallow groundwater on the western side of the Tulare Lake Region are also of concern. Figures II-18 and II-19 show concentrations of salinity and selenium, respectively, in the Tulare Lake Region. Figure II-20 shows problem areas for boron, molybdenum, and arsenic.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with high groundwater tables in the Tulare Lake Region. High groundwater tables along the west side of the Tulare Lake Region contribute to complications associated with agricultural subsurface drainage, and were previously discussed.

GROUNDWATER CONDITIONS IN THE SAN FRANCISCO BAY REGION

Groundwater resources in the San Francisco Bay Region vary throughout the area. Groundwater conditions discussed in this section are limited to CVP service areas for the counties of Santa Clara, San Benito, Alameda, and Contra Costa.

Santa Clara and San Benito Counties

Imported surface water from the CVP San Felipe Division is provided to areas in Santa Clara and San Benito counties. Water conveyed to these areas is intended to supplement available supplies, minimize groundwater mining, stabilize groundwater levels, arrest land subsidence, and improve water quality conditions.

Santa Clara County. Three interconnected groundwater basins are located within the Santa Clara County area: Santa Clara Valley Basin, Coyote Basin, and Llagas Basin (Reclamation, 1976b). Extensive groundwater pumping for agricultural purposes produced overdraft conditions in these groundwater basins, and resulted in land subsidence, increased pumping costs, and seawater intrusion from the San Francisco Bay. Local surface water facilities constructed in the 1940s eliminated most overdraft conditions by the 1950s, but subsequent increased development caused localized overdraft. To reverse these conditions, surface water was initially imported to the area in the 1960s through the SWP South Bay Aqueduct. Continued growth during the late 1960s and 1970s threatened to return the area to overdraft conditions. These concerns were dampened by additional surface water imports to the area from the San Felipe Division of the CVP in the 1980s. Much of this imported water is distributed to percolation ponds for groundwater recharge, and the remainder is further distributed for direct use and storage.

Prior to the SWP and CVP surface water imports, groundwater overdraft resulted in land subsidence in parts of Santa Clara County. Between 1912 and 1933, a maximum land subsidence of 4.0 feet was recorded near the cities of Santa Clara and San Jose. USGS mapping of these areas from 1934 to 1960 and from 1960 to 1967 shows that the maximum land subsidence was 8.0 and 3.5 feet, respectively. Total land subsidence at one benchmark in the Santa Clara Valley between 1912 and 1969 was 13.0 feet (Reclamation, 1976b).

Groundwater resources in Santa Clara County are generally of good quality. Seawater intrusion is presumably responsible for high chloride concentrations in the northern Santa Clara Valley basin in the tideland area of San Francisco Bay. Limited areas of high boron and high magnesium concentrations in groundwater on the east side of the basin have been observed, possibly due to seepage of small streams draining from the Diablo Range. Wells in the Los Altos, Morgan Hill, and Gilroy areas have reported high nitrate concentrations.

San Benito County. Groundwater resources in the San Benito County (Hollister area) consist of numerous subbasins partially separated by barriers, generally fault zones, which crisscross the area. Irrigation of agricultural lands in this area has relied on groundwater as the primary supply. As historical agricultural development expanded, groundwater withdrawals began to exceed groundwater recharge causing severe declines in groundwater levels. In the 1980s, surface water was imported to the Hollister area from the San Felipe Division of the CVP for the purposes of alleviating the degenerating groundwater conditions. Because of the complex geological fault system, direct groundwater recharge is limited, and imported water is distributed primarily for direct use and storage.

Prior to the completion of the San Felipe Division of the CVP, groundwater levels declined as much as 100 feet from pre-irrigation times. Groundwater quality in the area is generally good, however, the declining groundwater levels raised concern regarding potential deterioration of the quality of the groundwater (Reclamation, 1976b).

Alameda and Contra Costa Counties

Groundwater resources in parts of Alameda and Contra Costa counties are limited due to availability of supply, and poor water quality. In areas of limited groundwater supply, this has resulted in reliability problems, excessive groundwater level declines and land subsidence, increased pumping costs, and further degradation of water quality conditions. The introduction of imported CVP surface water supplies has supplemented these limited supplies.

GROUNDWATER MANAGEMENT AND CONJUNCTIVE USE PROGRAMS

Groundwater management and conjunctive use programs have influenced the present conditions of California's groundwater resources. Following is a brief summary of existing programs.

Existing Management Policies

DWR defines groundwater management as (DWR, 1994):

> "Protection of natural recharge and use of intentional recharge; planned variation in amount and location of extraction over time; use of groundwater storage conjunctively with surface water from local and imported sources; and protection and planned maintenance of groundwater quality."

The type of groundwater management and extent of that management varies. Some groundwater management is by statute, and other is a result of court ordered decisions. These distinguishing aspects are discussed below.

Existing law regarding groundwater is controlled by jurisdictional decisions. In the 1903 case of *Katz v. Walkinshaw*, the concept of overlying right was established. This suggests that all property owners above a common aquifer possess a mutual right to use of a reasonable groundwater resource on their land overlying the aquifer. Other than this overlying right, no limits are set on groundwater use, except in adjudicated basins throughout California. DWR identifies 13 adjudicated groundwater basins (DWR, 1994). No adjudicated basins lie in the Central Valley area or San Francisco Bay Region.

The California Water Code provides limited authority to deal with groundwater by allowing the formation of special districts (or water agencies) through general or special legislation. DWR identifies nine groundwater management agencies formed by such special legislation (DWR, 1994), none of which lie within the Central Valley area or San Francisco Bay Region.

A third means of groundwater management exists for surface water agencies that can show that surface water delivered to a given area recharges a local aquifer. Several agencies have used this statutory authority granted by the legislature to levy charges for groundwater extraction. Agencies that have exercised this authority are Rosedale-Rio Bravo Water Storage District in the Tulare Lake Region, and Santa Clara Valley Water District in the San Francisco Bay Region.

Groundwater management plans can be adopted by certain local agencies based on California Water Code section 10750. More than 40 agencies have expressed interest in using that section of the code (DWR, 1994). The management plan provides authority to fix and collect fees and assessments for costs associated with implementation of the plan. If a majority of the land owners affected protest the adoption of the plan, the groundwater management plan shall not be adopted.

Existing Conjunctive-Use Programs

DWR defines conjunctive use as (DWR, 1994):

- "Conjunctive use is the operation of a groundwater basin in coordination with a surface water system to increase total water supply availability, thus improving the overall reliability of supplies. The basin is recharged, both directly and indirectly, in years of above-average precipitation so that groundwater can be extracted in years of below average precipitation when surface water supplies are below normal."

According to this definition, various forms of conjunctive use are present throughout California. The form of conjunctive use ranges from incidental conjunctive use benefits to rigorous management programs implemented through detailed operating guidelines. For the purposes of this discussion conjunctive use is characterized as either incidental conjunctive use, active substitution, or artificial recharge. These three types of conjunctive use can occur individually or may be used in conjunction with one another. In DWR's recent California Water Plan Update (Bulletin 160-93), some of the major programs in place today were highlighted and are discussed below. However, this is not a complete summary of all conjunctive use programs currently in operation or planned.

Incidental Conjunctive Use. Incidental conjunctive use occurs when an area relies on surface water when it is available, and on groundwater when surface water is not available. This is the basic level of conjunctive use. The development of surface water storage and delivery projects by Reclamation, DWR, and others has been an important factor in allowing water users to reduce groundwater pumping and build up groundwater storage for future use. Management techniques may be used to define the timing and location of surface water deliveries and groundwater pumping, in order to maximize water supply reliability.

Two examples of this type of conjunctive use are present in the Sacramento River Region and are managed by the South Sutter Water District (SSWD) and Yolo County Flood Control and Water Conservation District (YCFCWCD). SSWD historically relied on groundwater. With the onset of regional groundwater level declines, the district developed surface water supplies on the Bear River by constructing Camp Far West Reservoir. This district is investigating ways to better utilize the surface water and available groundwater without extended drawdowns of the groundwater table. YCFCWCD does not rely on groundwater though they do provide surface water supplies from Clear Lake and Indian Valley Reservoir to farmers that utilize groundwater. The district is working with the farmers to assist in managing the local groundwater resources in conjunction with the available surface water.

Numerous water users in the San Joaquin River and Tulare Lake regions also participate in this type of conjunctive use activity. For example imported surface water supplies provided by the CVP and SWP lessen the burden on groundwater supplies for purposes of reducing groundwater overdraft. However, groundwater pumping may increase in years of below-average precipitation conditions and availability of imported surface water supplies.

Active Substitution. Active substitution as a conjunctive use method brings additional surface water into an area as part of a trade with the water users of that area. Active substitution is the method that DWR is pursuing in the Sacramento Valley, in which they supply surface water to water users in wet years, reducing those water users need for groundwater. Then, in dry years, these water users rely primarily on groundwater, and free up their surface water supply to DWR for use elsewhere.

A recent example incorporating aspects of active substitution is DWR's State Drought Water Bank. The state operated the State Water Bank transfers in 1991 and 1992 which transferred surface water from areas north of the Delta to areas in need of imported surface water supplies south of the Delta. Some groundwater pumping replaced transferred water that was acquired from sources north of the Delta.

Artificial Recharge. Conjunctive use programs incorporating artificial recharge methods require a source of surface water (imported or reclaimed) that is not needed for immediate use. The surface water is placed directly into the ground by various means, including spreading ponds and injection. This water is then available for use in dry periods. This is a common practice in many areas of the state, especially in the San Joaquin River and Tulare Lake regions. Several artificial recharge programs are currently in operation or planned for future operation in the Tulare Lake Region. In Kern County, Rosedale-Rio Bravo Water Storage District purchases surface water from three sources and recharges local groundwater reserves. These groundwater reserves are then later tapped for irrigation purposes. Arvin-Edison Water Storage District (AEWSD) and the Metropolitan Water District of Southern California (MWD) are forming a conjunctive-use partnership in which AEWSD would provide CVP supplies to MWD in dry years, replacing this supply with groundwater previously recharged by SWP supplies made available by MWD. The Kern Water Bank project, which has been in operation for a number years, augments SWP supplies with groundwater in drought years.

Conjunctive use of surface water and groundwater is regionally extensive in the east side of the San Joaquin River and Tulare Lake regions. For example, surface water management in the Kings and Kaweah river basins is used to provide groundwater recharge. This area is also served by the Friant-Kern Canal, which delivers CVP water for direct use and groundwater recharge purposes. In the San Joaquin River Region, the integrated operation of the Madera Canal, together with Hidden Dam and Buchanan Dam on the Fresno and Chowchilla Rivers, respectively, also involves extensive groundwater recharge.

In the San Francisco Bay Region, the Santa Clara Valley Water District (SCVWD) manages imported SWP and CVP water supplies, providing treatment of water for immediate use or delivering the water to recharge sites. The basin is managed to provide groundwater carryover storage, eliminate land subsidence and seawater intrusion caused by groundwater overdraft, and provide a buffer for dry years when imported surface water supplies are reduced.

It is important to note that conjunctive use of surface water and groundwater is extensive throughout the Central Valley and Santa Clara Valley areas. In addition, the methods of conjunctive use may involve one or a combination of the types of conjunctive use discussed above.

CHAPTER III

ENVIRONMENTAL CONSEQUENCES

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Chapter III

ENVIRONMENTAL CONSEQUENCES

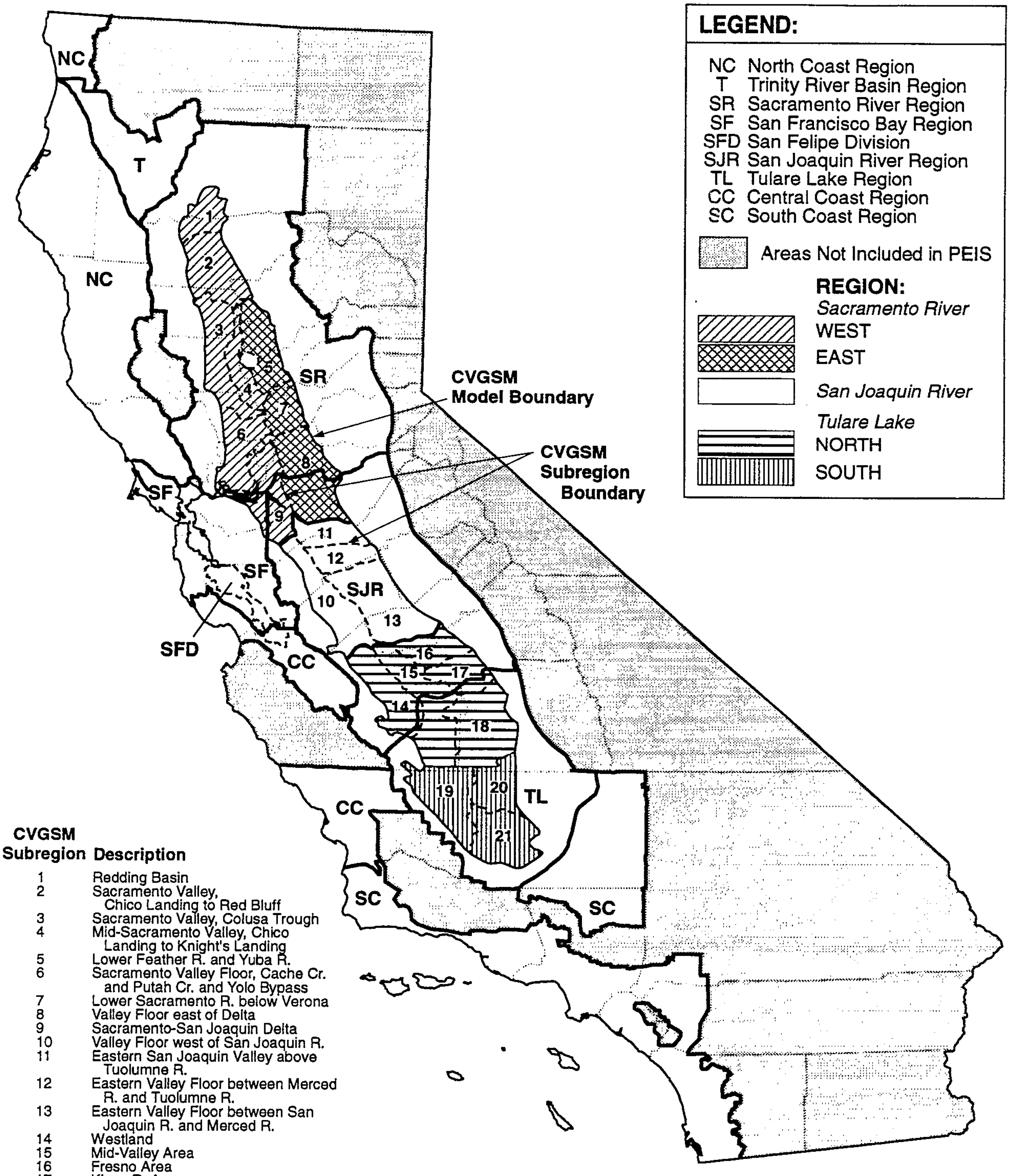
INTRODUCTION

This section describes changes to groundwater conditions associated with the CVPIA alternatives, as compared to the No-Action Alternative. Changes in groundwater conditions are presented for the study area shown in Figure III-1, based on a quantitative analysis of the Central Valley region, and a qualitative analysis of groundwater resources associated with CVP service areas in the San Francisco Bay Region. Supplemental analyses were completed on the main alternatives for specific technical issues for the purposes of identifying results of specific actions. Only those supplemental analyses resulting in impacts to groundwater conditions of the Central Valley and San Francisco Bay Region are discussed. For purposes of comparing groundwater impacts for each alternative on a relative scale, groundwater conditions under the No-Action Alternative are described. Groundwater conditions for each alternative are compared to the No-Action Alternative, and associated impacts are reported. The following alternatives are discussed in this chapter:

- Alternative 1
- Supplemental Analysis 1a
- Supplemental Analysis 1d
- Alternative 2
- Alternative 3
- Alternative 4

The Sacramento River, San Joaquin River, and Tulare Lake regions were selected to aid in the presentation of the quantitative analysis of groundwater resources by grouping areas of similar impacts together. In certain alternatives, specific areas within a particular region responded to a particular action. For this reason the Sacramento River Region is split into west and east regions and the Tulare Lake Region is split into north and south regions to aid in identifying the impacts associated with these actions. It was not necessary to split the San Joaquin River Region into geographically unique areas since the impacts to groundwater conditions are more uniformly distributed throughout this region. Additional details of the quantitative analysis are provided for the 21 Central Valley subregions and are included as Attachment B. Consistent with the purposes of a PEIS, specific conclusions regarding beneficial or adverse impacts of these effects are not evaluated in this chapter.

Groundwater impacts for each alternative are summarized as changes to groundwater storage, groundwater levels, and land subsidence as compared to the No-Action Alternative. These conditions represent the general response of groundwater basins to changes in crop mix and irrigation technologies, surface water and groundwater use, and streamflow. Changes in groundwater storage are summarized for long-term average annual conditions. These changes



CVGSM Subregion	Description
1	Redding Basin
2	Sacramento Valley, Chico Landing to Red Bluff
3	Sacramento Valley, Colusa Trough
4	Mid-Sacramento Valley, Chico Landing to Knight's Landing
5	Lower Feather R. and Yuba R.
6	Sacramento Valley Floor, Cache Cr. and Putah Cr. and Yolo Bypass
7	Lower Sacramento R. below Verona
8	Valley Floor east of Delta
9	Sacramento-San Joaquin Delta
10	Valley Floor west of San Joaquin R.
11	Eastern San Joaquin Valley above Tuolumne R.
12	Eastern Valley Floor between Merced R. and Tuolumne R.
13	Eastern Valley Floor between San Joaquin R. and Merced R.
14	Westland
15	Mid-Valley Area
16	Fresno Area
17	Kings R. Area
18	Kaweah R. and Tule R. Area
19	Western Kern County
20	Eastern Kern County
21	Kern River Area

FIGURE III-1
GROUNDWATER STUDY AREA

indicate the ability of a groundwater basin to support water and land use management practices for each alternative. Groundwater levels at the end of the 69-year simulation period are compared between each alternative and the No-Action Alternative. The end of the simulation period was chosen in order to represent long-term differences in groundwater conditions. Groundwater level differences provide a measure of associated groundwater impacts such as pumping costs, changes in groundwater-surface water interaction, migration and upwelling of poor-quality groundwater, impairment of subsurface drainage systems in areas of poorly drained soils, and high groundwater tables adjacent to streams with known seepage-induced waterlogging problems. These potential problems are all inferred from groundwater level differences between each alternative and the No-Action Alternative and are discussed qualitatively below, with the exception of pumping costs discussed in the Agricultural Economics Technical Appendix.

Declining groundwater levels can also be indicative of potential land subsidence in areas where clay and silt lenses susceptible to compaction are prevalent. The occurrence of land subsidence can damage water conveyance facilities, flood control and drainage levee systems, groundwater well casings, and other infrastructure. Potential land subsidence impacts for each alternative as compared to the No-Action Alternative are based on long-term land subsidence, which for this analysis is derived from the end of the 69-year simulation period.

The impact assessment methodology is discussed in the following section. This is followed by a presentation of groundwater conditions under the No-Action Alternative, and groundwater impacts associated with each alternative as compared to the No-Action Alternative. The groundwater conditions and related impacts can only be interpreted comparatively, and are not to be viewed as possible projected conditions on an individual basis. Furthermore, the No-Action Alternative is based upon specific assumptions, guidelines, and screening criteria developed specifically for the CVPIA PEIS. Groundwater conditions for the No-Action Alternative may differ from those represented by baseline conditions developed for other efforts, such as those reported by DWR in Bulletin 160-93 (for additional information please see Attachment C).

IMPACT ASSESSMENT METHODOLOGY

The groundwater resources analysis for the PEIS focused on the Central Valley aquifer system. To analyze impacts on the groundwater in the valley aquifers, the aquifer system was simulated using the Central Valley Groundwater-Surface Water Simulation Model (CVGSM). Initial groundwater levels for the simulation were set to September 1990 levels. Groundwater conditions were simulated using a 69-year historical hydrologic period (1922-1990) under specified projected-level land use conditions. The 69-year historical hydrologic period spans varied dry, wet, and normal hydrologic conditions. Imposing these conditions on the regional aquifer system provides a range of possible impacts.

Monthly water demands, not met by precipitation, for agricultural, urban, and refuge purposes were developed on a subregional basis. Agricultural demands are calculated on a monthly basis using a consumptive use approach. This approach accounts for varied hydrologic conditions, soil types, potential evapotranspiration, and irrigation efficiencies. Urban and refuge demands are based on annual projections for average hydrologic conditions. These demands are distributed monthly based on recent average monthly historical demands. Though these projected demands can vary from year to year depending upon hydrologic conditions, these variations are small given the proportion of urban and refuge demands relative to total demands in the Central Valley. Surface water supplies are defined by major source and are distributed on a subregional basis. All water demands not net by surface water supplies for a given subregion are generally assumed to be met by groundwater pumping within that subregion, subject to limitations as defined by a particular alternative. This groundwater pumping is estimated by CVGSM during the simulation process. Additional discussion regarding the development of water demands and water supplies is provided in the CVGSM Methodology/Modeling Technical Appendix.

The CVGSM provides water budgets, groundwater levels, groundwater gradients, and land subsidence (land subsidence is simulated by the CVGSM Land Subsidence Simulation Model), all of which are used to compare alternatives. The specified conditions, assumptions, and procedures used to simulate groundwater hydrology in the Central Valley for the PEIS alternatives are discussed in the CVGSM Methodology and Modeling Technical Appendix. Groundwater conditions in the San Francisco Bay Region were not simulated for the PEIS, and are assessed qualitatively for CVP service areas in this region based on changes due to reductions in CVP surface water deliveries.

GROUNDWATER STORAGE AND PRODUCTION

Regional groundwater levels fluctuate similarly to groundwater storage from wet to dry to average hydrologic conditions. Changes in simulated regional groundwater storage are used to evaluate groundwater impacts of the alternatives. In addition, simulated regional changes in discharge and recharge are compared between the alternatives and the No-Action Alternative to demonstrate their relationship to changes in simulated groundwater storage.

GROUNDWATER LEVELS

Simulated groundwater levels are used as an overall spatial representation of the difference in storage between the alternatives. Major groundwater depression areas are compared between the No-Action Alternative and each of Alternatives 1 through 4, and Supplemental Analysis 1a and 1d, based on groundwater levels at the end of the 69-year simulation period. For the purposes of the impact assessment the average of layer 1 and layer 2 groundwater levels is reported. In the simulation model these are represented as unconfined layers, except where layer 2 is confined by the Corcoran Clay Member in the San Joaquin River and Tulare Lake regions. Layer 1 and layer 2 are the primary producing zones. An average of the two layers provides a reasonable representation of likely groundwater levels under simulated conditions. In areas of confinement, the issue of differences in drawdown occurring in the confined zone relative to the reporting of the average groundwater levels is addressed by considering the average long-term decline in layer 2 groundwater levels in comparison to the average long-term decline of layers 1 and 2 combined.

LAND SUBSIDENCE

The simulated land subsidence (resulting from groundwater level declines) for the alternatives are compared to the No-Action Alternative. Simulated land subsidence was generated with the CVGSM Land Subsidence simulation model. For this programmatic level study, the range of differences in land subsidence (reported at the end of the simulation period) between the alternatives and the No-Action Alternative are reported regionally.

GROUNDWATER QUALITY

The groundwater gradients simulated by CVGSM for the alternatives are compared to the No-Action Alternative to assess potential changes in the rate and/or direction of poor-quality groundwater migration. For this programmatic level study, these gradients are generalized and are based on a regional qualitative analysis. The movement of groundwater between layers for the alternatives are compared to the No-Action Alternative to assess potential changes in groundwater quality due to upwelling of poor-quality groundwater into productive groundwater zones of better quality.

AGRICULTURAL SUBSURFACE DRAINAGE

Agricultural subsurface drainage problems occurring in the Sacramento River Region, and problems originating along the west side of the San Joaquin Valley basin within the San Joaquin River and Tulare Lake regions, will be addressed qualitatively. Slowly permeable layers in the soil profile restrict natural drainage to the extent that if often must be supplemented with constructed facilities for irrigated agriculture to be sustained. Factors that could affect the subsurface drainage conditions include changes in groundwater levels, changes in groundwater gradients, and changes in water use and land use patterns. The impacts to subsurface drainage are inferred from groundwater levels and groundwater movement simulated by CVGSM. Impacts associated with water use and land use patterns are discussed in the Water Facilities and Supplies Technical Appendix and the Agricultural Economics Technical Appendix.

SEEPAGE AND WATERLOGGING

Exceedence diagrams have been developed for summer flows (May through August) to demonstrate the impact of the alternatives, as compared with the No-Action Alternative, on the percent of time streamflows could be expected to exceed the level that can cause seepage-induced waterlogging of adjacent low-lying farm lands. For the Sacramento River Region this analysis was conducted for three Sacramento River reaches. Simulated streamflows were obtained from the surface water facilities analysis for Colusa Weir to Fremont Weir reach, the Fremont Weir to American River reach, and the American River to Hood reach. These reaches are represented by simulated flows at PROSIM nodes 7, 13, and 17, respectively (see the PROSIM Methodology and Modeling Technical Appendix for additional information about these locations). For the San Joaquin River Region exceedence diagrams were prepared for San Joaquin River at Vernalis to represent conditions in the lower reaches of the San Joaquin River and its tributaries. This reach is represented by simulated flows at SANJASM node 125 (see the SANJASM Methodology and Modeling Technical Appendix for additional information about the this location). A threshold of 16,000 cfs, discussed in Chapter II, for crop damage from seepage-induced waterlogging is assumed for the San Joaquin River analysis. Threshold flows are not available for the Sacramento River reaches. Instead, impacts are inferred based on a relative comparison of each alternative with the No-Action Alternative.

NO-ACTION ALTERNATIVE

The No-Action Alternative provides a base condition for comparison with each of the PEIS alternatives. The No-Action Alternative represents conditions in the future assuming a projected 2020 level of development without implementation of CVPIA. The major components and assumptions of the No-Action Alternative affecting the groundwater resources of the Central Valley are land use, demands, water supplies, and streamflows.

Projected Land Use is based on 2020 conditions, and is assumed to be held constant over the 1922 to 1990 simulation period. Projected urban acreage for 2020 is from DWR Bulletin 160-93. Projected agricultural acreage for 2020 is from the agricultural production analysis. These land use conditions are assumed to include the retirement of 45,000 acres of agricultural land by 2020 identified in the SJVDP. This is consistent with DWR Bulletin 160-93, which assumes the total agricultural land retirement of 75,000 recommended by the SJVDP, will occur proportionally between 1990 and 2040.

Projected Demands for urban, agricultural, and refuge needs are based on 2020 conditions. Urban demands for 2020 are from DWR Bulletin 160-93. Agricultural demands for 2020 are calculated using DWR's Consumptive Use model, and agricultural acreages and irrigation efficiencies from the agricultural production analysis. Refuge demands for 2020 are represented by refuge deliveries, and are from the water facilities analysis.

Surface Water Diversions for 2020 conditions are provided by the water facilities analysis. Surface water diversions not covered explicitly by this analysis are estimated based on recent historical conditions (see the CVGSM Methodology and Modeling Technical Appendix for additional details).

Groundwater Pumping for 2020 conditions are estimated using CVGSM. For the No-Action Alternative any demands not met by surface water are assumed to be met by groundwater pumping. This is compatible with current California law governing groundwater usage in the Central Valley.

Stream Inflows and Minimum Flow Requirements for 2020 conditions are based on the water facilities analysis. Inflows for streams not covered explicitly by this analysis are based on DWR depletion area modified outflows for 2020 C9A hydrology and historical gaged flows.

Details regarding the development of 2020 level data for the No-Action Alternative groundwater analysis are provided in the CVGSM Methodology and Modeling Technical Appendix. An assessment of simulated groundwater conditions for the No-Action Alternative are summarized below.

SACRAMENTO RIVER REGION

Groundwater Storage and Production

Sacramento River Region (West). Average annual groundwater conditions for the Sacramento River Region (West) under the No-Action Alternative are presented in Table III-1.

TABLE III-1

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SACRAMENTO RIVER REGION (WEST) (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	1667	1,686	1,695	1,684	1,684	19	28	17	16
Gain from Streams	255	267	260	267	272	12	5	12	16
Recharge (3)	32	32	32	32	32	0	0	0	0
Boundary Inflows (4)	79	81	78	74	75	2	-1	-5	-4
Total Recharge	**2,034**	**2,066**	**2,065**	**2,057**	**2,062**	**32**	**31**	**23**	**28**
Discharge									
Groundwater Pumping	2,038	2,076	2,074	2,066	2,071	37	35	27	33
Total Discharge	**2,038**	**2,076**	**2,074**	**2,066**	**2,071**	**37**	**35**	**27**	**33**
Change in Groundwater Storage (5)	**-5**	**-10**	**-9**	**-9**	**-9**	**-5**	**-4**	**-4**	**-4**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

Annual groundwater pumping averaged 2,038,000 acre-feet per year, ranging from approximately 1,600,000 acre-feet per year to 3,200,000 acre-feet per year. This range is a result of groundwater supplies making up for fluctuations in surface water supplies. Annual groundwater recharge (total) in the Sacramento River Region (West) averaged 2,034,000 acre-feet per year, ranging from approximately 1,500,000 acre-feet per year to 2,750,000 acre-feet per year. Under the conditions of the No-Action Alternative, deep percolation of rainfall and applied irrigation water, on a regional basis, are responsible for more than 80 percent of the average annual recharge in this area. The year-to-year variations in annual groundwater pumping and recharge are shown in Figure III-2.

Groundwater storage conditions in the Sacramento River Region (West) are shown in Figure III-3. Relative to conditions at the beginning of the simulation period, groundwater storage proceeds through phases of net groundwater storage depletion during extended drought periods, followed by a net recovery to pre-drought storage conditions. The largest decline in groundwater storage was approximately 3,700,000 acre-feet, occurring over a six-year period. However, the basin fully recovered from this depleted storage condition during the following eight years of the simulation, due to wetter than average hydrologic conditions during parts of this period. The net change in groundwater storage over the 69-year simulation period is -330,000 acre-feet.

Sacramento River Region (East). Average annual groundwater conditions for the Sacramento River Region (East) under the No-Action Alternative are presented in Table III-2. Annual groundwater pumping averaged 1,785,000 acre-feet per year, ranging from approximately 1,500,000 acre-feet per year to 2,700,000 acre-feet per year. As in the western area of the region, groundwater supplies fluctuate in response to varying surface water supplies. The relative range in variation, however, is smaller in this area because of the greater presence of urban surface water deliveries which exhibit fewer fluctuations annually than agricultural surface water deliveries. Annual groundwater recharge (total) in the Sacramento River Region (East) averaged 1,725,000 acre-feet per year, ranging from approximately 1,400,000 acre-feet per year to 2,300,000 acre-feet per year. The year-to-year variations in annual groundwater pumping and recharge are shown in Figure III-4. A small trend of increasing annual recharge occurs over the course of the simulation period. This trend is a result of increasing rates of stream seepage as groundwater levels decline during the simulation period.

Groundwater storage conditions for the Sacramento River Region (East) are shown in Figure III-5. Relative to conditions at the beginning of the simulation period, groundwater storage proceeds to decline over the course of the simulation period. The net total change in groundwater storage over the 69-year simulation period is -4,165,000 acre-feet. More than 80 percent of this decline occurs during the first 12 years, after which the rate of decline becomes more gradual for the remainder of the simulation period.

Groundwater Levels

Groundwater levels (in feet above mean sea level) representing the end of the 69-year simulation of the No-Action Alternative are shown in Figure III-6. Along the west side of the Sacramento River Region the groundwater gradient tends to follow hydrographic features, except for a groundwater depression in the Yolo County area. North of this area the range of long-term average groundwater level declines is from less than 1 foot to 10 feet. These conditions suggest that the groundwater basin is near a state of equilibrium, as supported by the small change in the

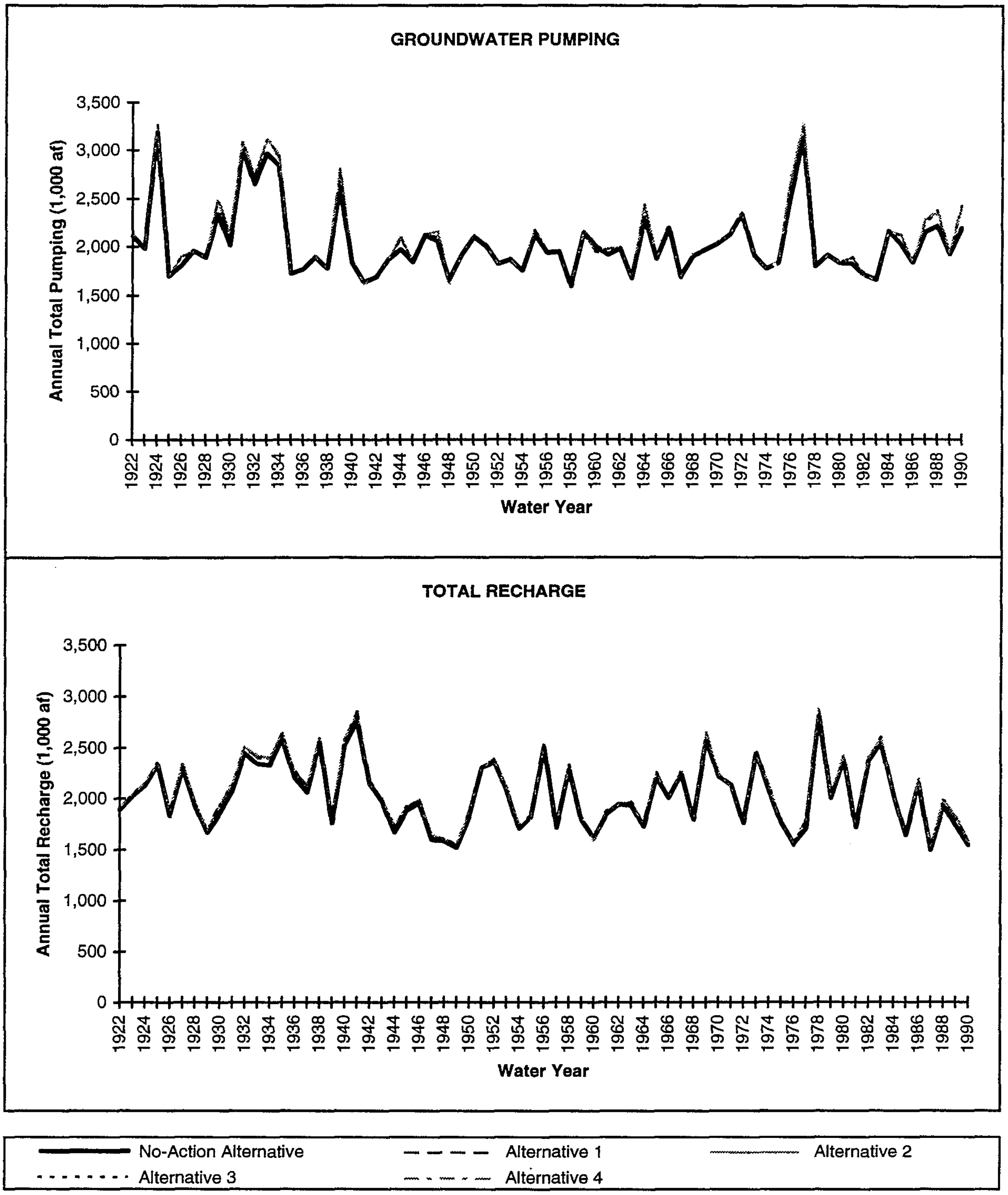


FIGURE III - 2
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SACRAMENTO RIVER REGION (WEST) FOR ALTERNATIVES 1 THROUGH 4

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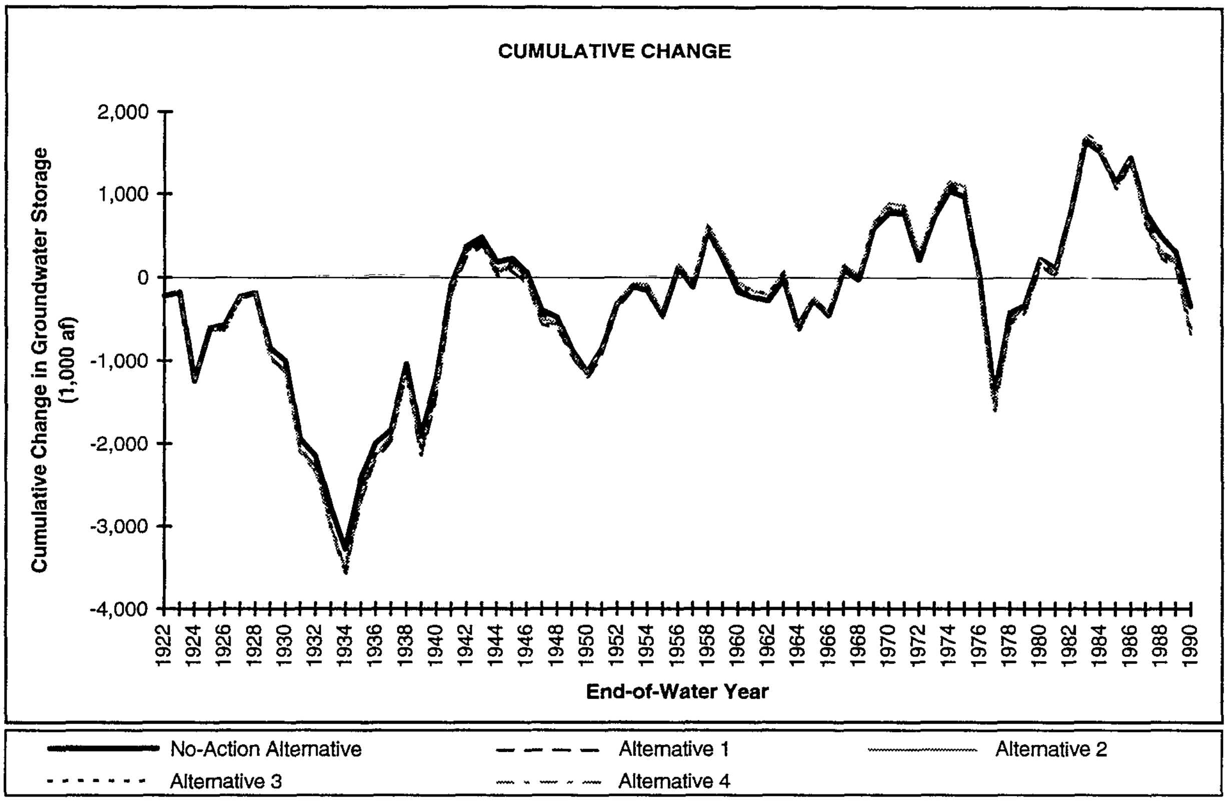

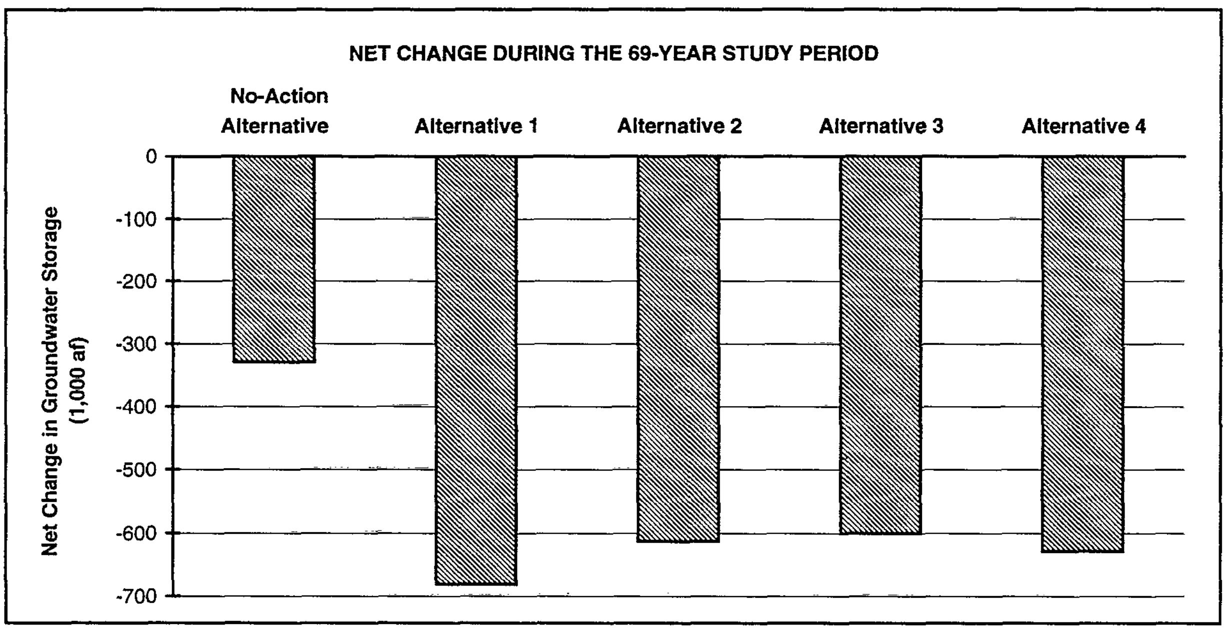

FIGURE III - 3
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SACRAMENTO RIVER REGION (WEST) FOR ALTERNATIVES 1 THROUGH 4

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TABLE III-2

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SACRAMENTO RIVER REGION (EAST) (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	819	828	830	811	811	10	11	-8	-8
Gain from Streams	516	528	533	593	595	12	17	77	79
Recharge (3)	24	24	24	24	24	0	0	0	0
Boundary Inflows (4)	366	372	372	373	373	6	7	7	7
Total Recharge	**1,725**	**1,753**	**1,760**	**1,802**	**1,803**	**28**	**35**	**77**	**78**
Discharge									
Groundwater Pumping	1,785	1,817	1,825	1,870	1,872	32	40	85	87
Total Discharge	**1,785**	**1,817**	**1,825**	**1,870**	**1,872**	**32**	**40**	**85**	**87**
Change in Groundwater Storage (5)	**-60**	**-64**	**-65**	**-69**	**-69**	**-4**	**-5**	**-8**	**-9**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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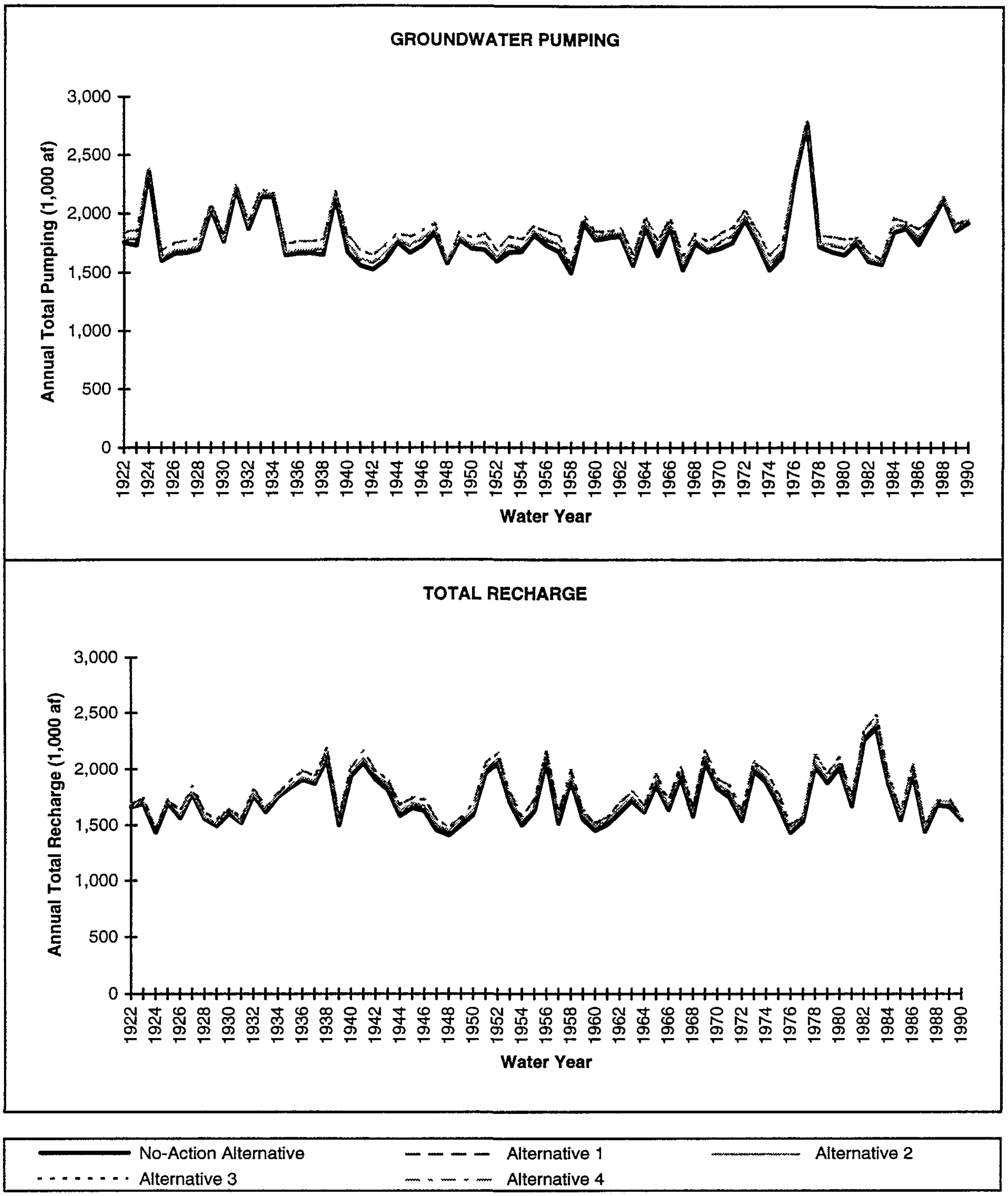

FIGURE III - 4
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SACRAMENTO RIVER REGION (EAST) FOR ALTERNATIVES 1 THROUGH 4

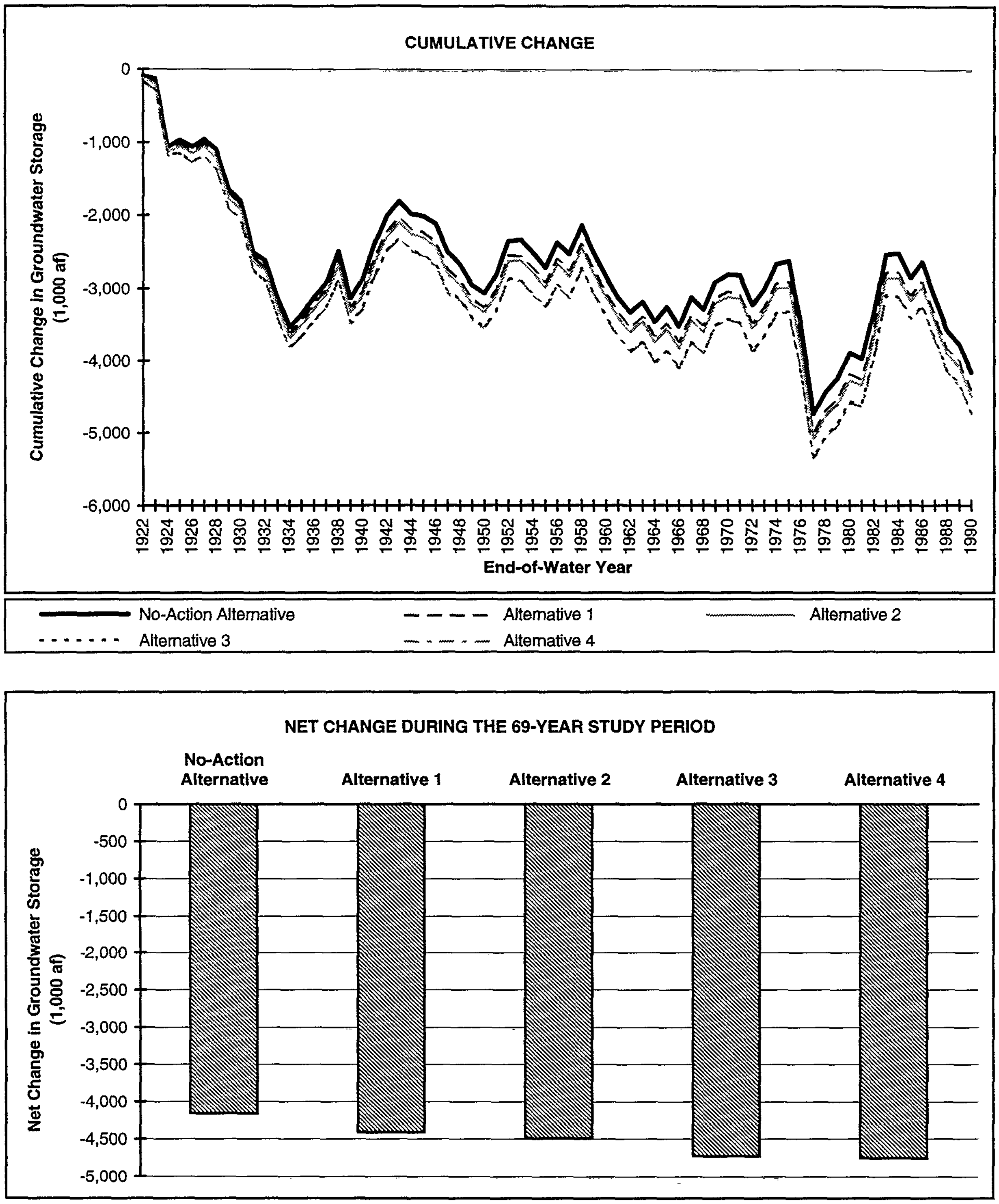

FIGURE III - 5
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SACRAMENTO RIVER REGION (EAST) FOR ALTERNATIVES 1 THROUGH 4

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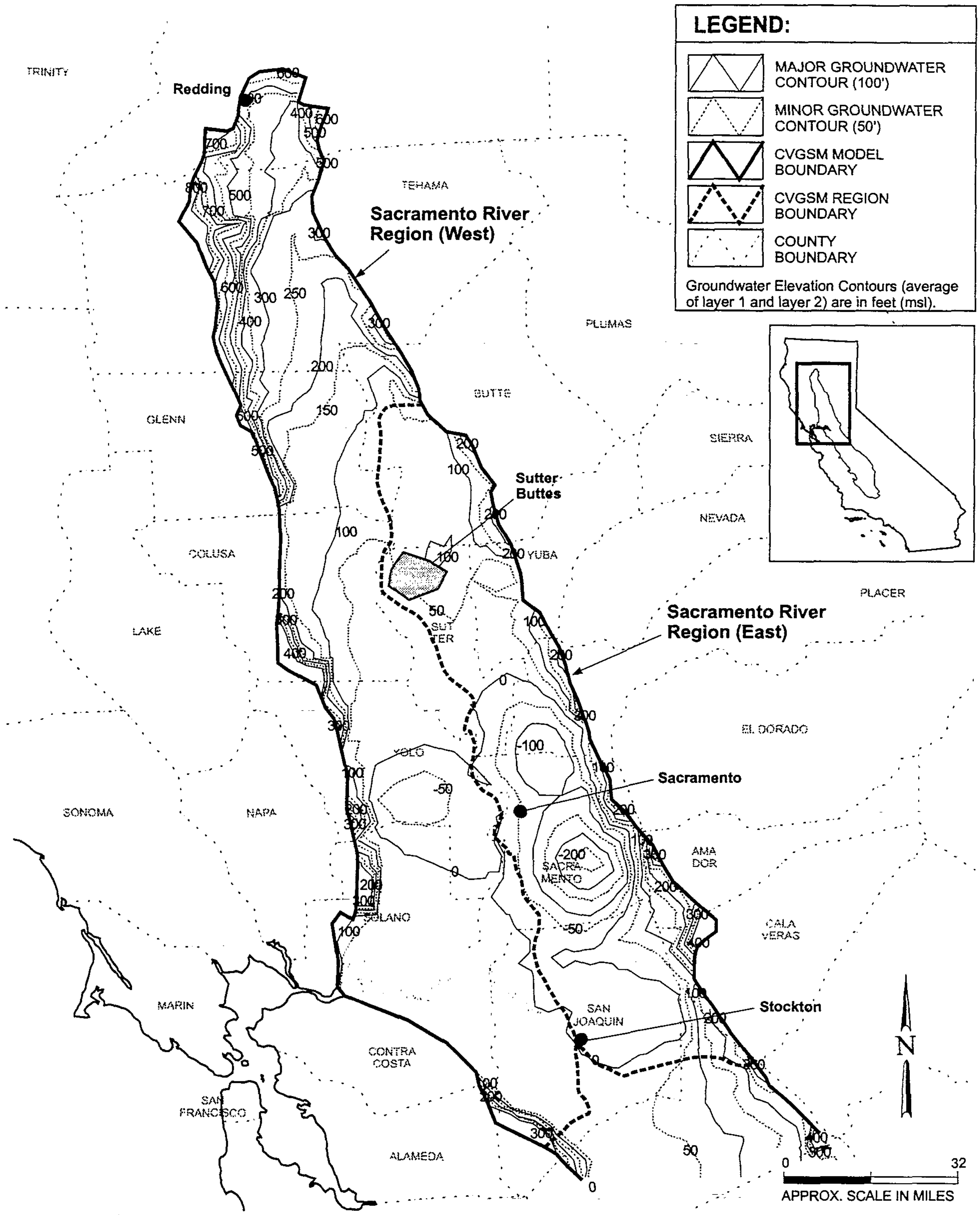

FIGURE III-6a

SACRAMENTO RIVER REGION END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR THE NO-ACTION ALTERNATIVE

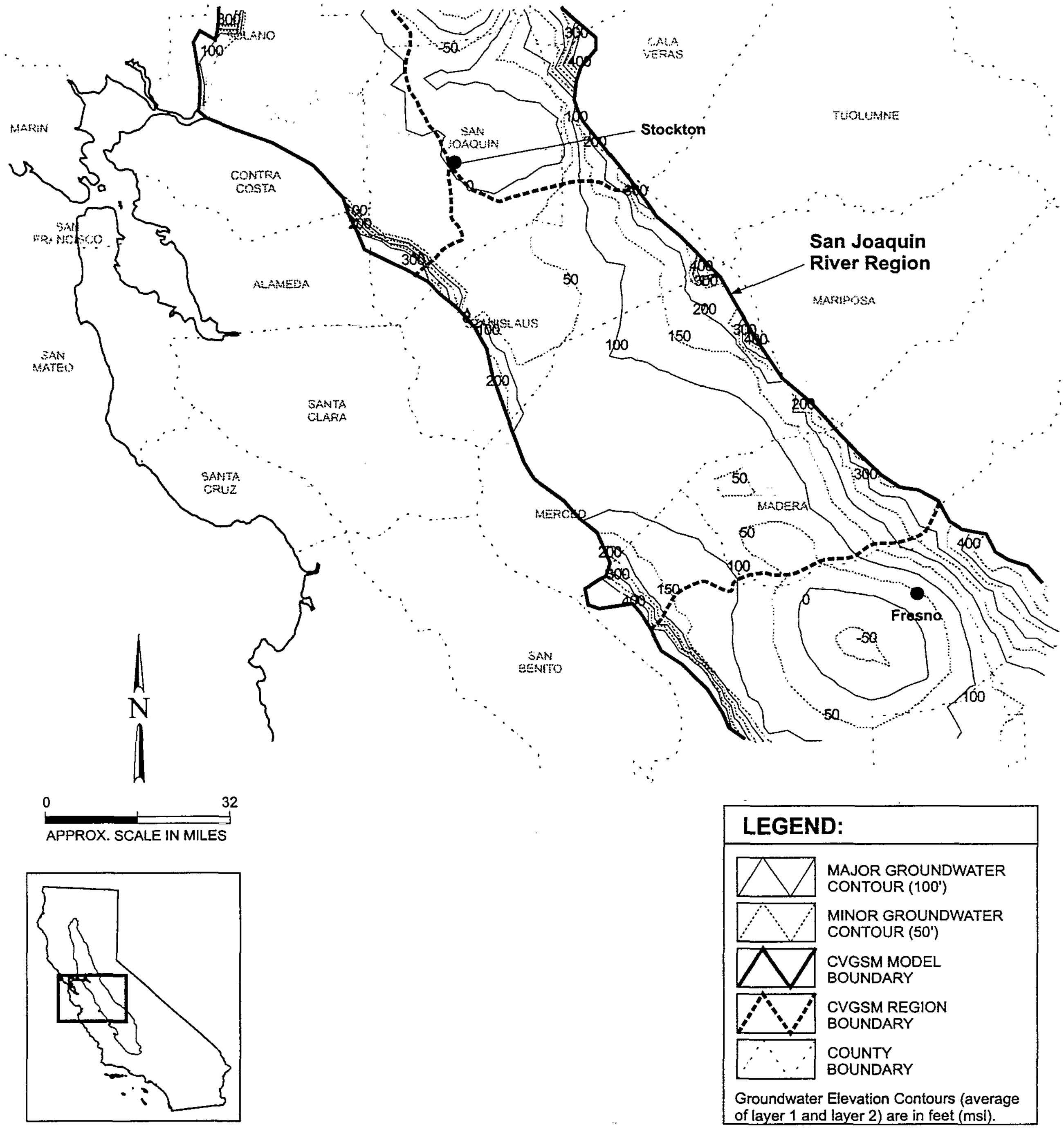

FIGURE III-6b

SAN JOAQUIN RIVER REGION END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR THE NO-ACTION ALTERNATIVE

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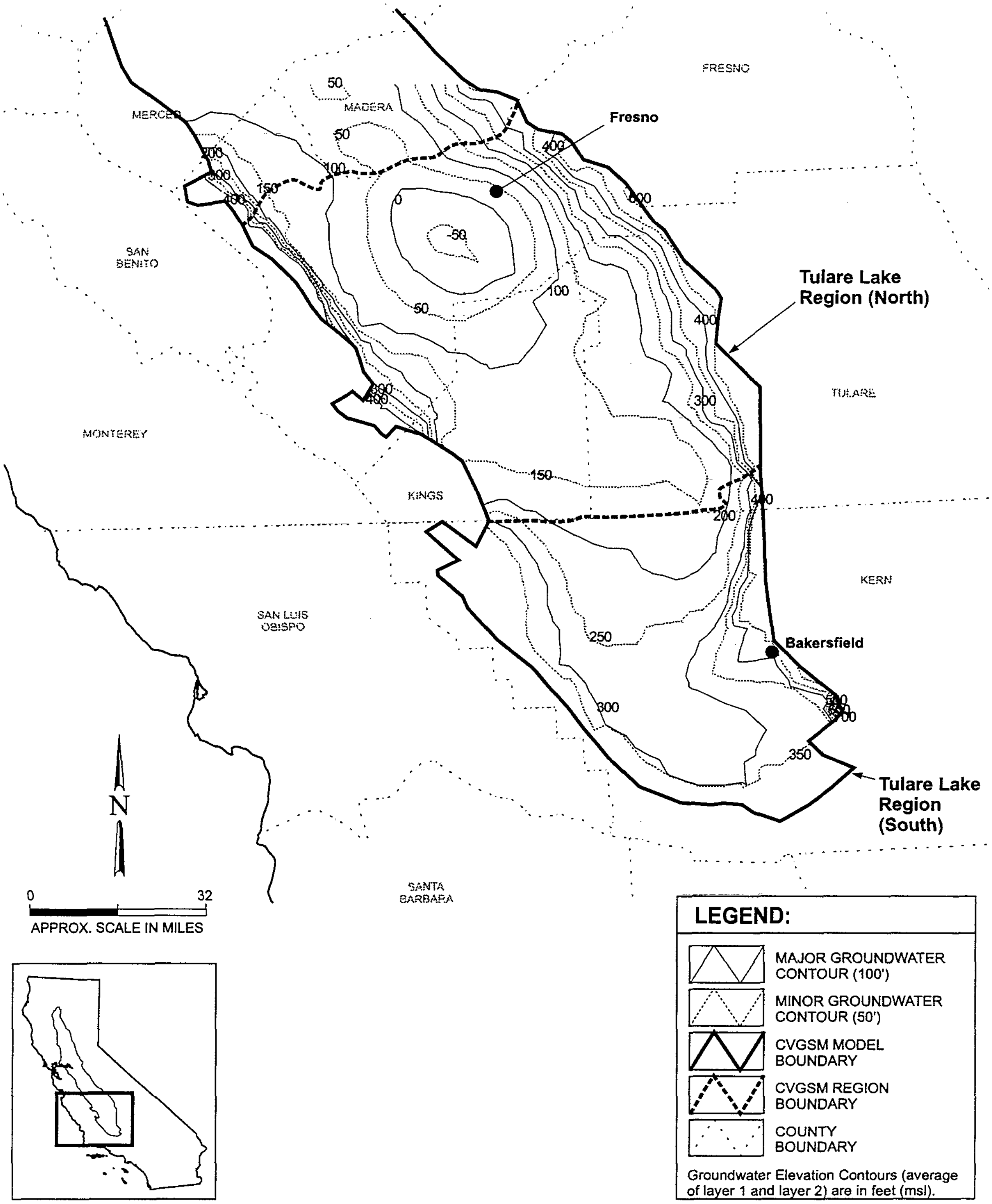

FIGURE III-6c

TULARE LAKE REGION END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR THE NO-ACTION ALTERNATIVE

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long-term average annual groundwater storage (see Table III-1). The hydraulic connection between streams and the underlying groundwater tables in this area would be maintained similar to recent historical conditions.

Groundwater levels on the east side of the Sacramento River Region are dominated by groundwater level depressions occurring north and south of the City of Sacramento, and in eastern San Joaquin County. These conditions are a reflection of groundwater use in excess of groundwater recharge, and would result in an average annual groundwater storage decline of 60,000 acre-feet. Hydraulic disconnection between partial stream reaches and underlying groundwater tables has developed historically in these areas, and under the No-Action Alternative would likely expand to affect larger reaches of these streams.

In the southwestern portion of the region groundwater levels at the end of the 69-year simulation are higher than recent historical conditions. This is due to several of issues, groundwater pumping being an important contributing factor. On average, annual groundwater pumping in the No-Action Alternative in comparison to groundwater pumping estimates used in the CVGSM calibration model are smaller. This results in an increase in groundwater storage initially, followed by a new equilibrium condition in the later part of the 69-year simulation, during which time groundwater levels remain relatively stable for the remainder of the simulation period.

Land Subsidence

Land subsidence is known to only occur in the southwestern part of the Sacramento Valley basin, in central Yolo County. Under the No-Action Alternative, with groundwater levels declining in this area, increased land subsidence would likely occur relative to recent historical conditions.

Groundwater Quality

Groundwater quality under the No-Action Alternative would likely be degraded due to the induced migration of groundwater, high in TDS, known to exist south of the Sutter Buttes and southern Yolo County, towards depressed groundwater levels to the south and east of these areas. Potential boron problems in central Yolo County could also contribute to groundwater quality degradation from this induced migration.

Agricultural Subsurface Drainage

Agricultural subsurface drainage problems in the Sacramento River Region under the No-Action Alternative would not be altered as a result of prevailing groundwater conditions, and are expected to be similar to recent historical conditions.

Seepage and Waterlogging

Average flows in the Sacramento River under the No-Action Alternative are similar to or lower than recent historical conditions in isolated areas subject to seepage-induced waterlogging. In addition, high groundwater tables did not encroach on these areas. It is expected that waterlogging of low-lying farm land in these areas under the No-Action Alternative would be similar to recent historical conditions.

SAN JOAQUIN RIVER REGION

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under the No-Action Alternative are presented in Table III-3. Annual groundwater pumping averaged 1,875,000 acre-feet per year, ranging from approximately 1,300,000 acre-feet per year to 3,200,000 acre-feet per year. The maximum pumping is more than 70 percent above average, indicative of the area's less abundant and more variable surface water supplies in comparison to the Sacramento River Region. Annual groundwater recharge averaged 1,849,000 acre-feet per year, ranging from approximately 1,200,000 acre-feet per year to 3,100,000 acre-feet per year. The year-to-year variations in annual groundwater pumping and recharge are shown in Figure III-7. The change in groundwater storage shown in Figure III-8 fluctuates annually in response to varied hydrologic and water supply conditions. Long-term groundwater storage conditions decline over the course of the 69-year simulation period, resulting in a net change of -1,859,000 acre-feet.

Groundwater Levels

Under the No-Action Alternative groundwater levels (in feet above mean sea level) at the end of the 69-year simulation on the east side of the San Joaquin River Region (Figure III-6b) generally follow hydrographic features associated with the San Joaquin River major tributaries. The hydraulic connection between these tributaries and underlying groundwater tables is similar to recent historical conditions. Along the west side groundwater levels vary gradually over much of the region. Groundwater levels in the extreme northern end decline towards a groundwater depression in eastern San Joaquin County, and in the southern end they decline in the direction of depressed groundwater levels occurring in Madera and Fresno counties. The Madera County area is responsible for a majority of the decline in average groundwater storage conditions occurring in this region under the No-Action Alternative. Large portions of this area (also known as the Madera Basin) are occupied by unincorporated agricultural lands that rely on groundwater to meet nearly all the applied water demands, contributing to the groundwater storage decline.

Where confined conditions of layer 2 exist and a majority of the groundwater pumping takes place, groundwater levels (piezometric head) associated with this aquifer zone exhibit a greater decline over the simulation period in comparison to the average of layer 1 and 2. For areas along the west side, average declines were 5 feet or more than the average of layer 1 and 2 for groundwater levels at the end of the simulation period.

Land Subsidence

Land subsidence is known to occur along the west side of the San Joaquin River Region. For the No-Action Alternative, increased land subsidence in this area would likely occur relative to recent historical conditions.

TABLE III-3

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SAN JOAQUIN RIVER REGION (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	1,077	1,086	1,071	1,005	1,000	9	-6	-72	-78
Gain from Streams	313	336	387	490	494	22	73	176	181
Recharge (3)	434	447	418	368	371	13	-16	-66	-63
Boundary Inflows (4)	24	14	19	49	37	-10	-6	25	13
Total Recharge	**1,849**	**1,883**	**1,894**	**1,912**	**1,902**	**34**	**45**	**64**	**54**
Discharge									
Groundwater Pumping	1,875	1,915	1,928	1,949	1,944	39	53	74	69
Total Discharge	**1,875**	**1,915**	**1,928**	**1,949**	**1,944**	**39**	**53**	**74**	**69**
Change in Groundwater Storage (5)	**-27**	**-32**	**-34**	**-37**	**-42**	**-5**	**-7**	**-10**	**-15**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

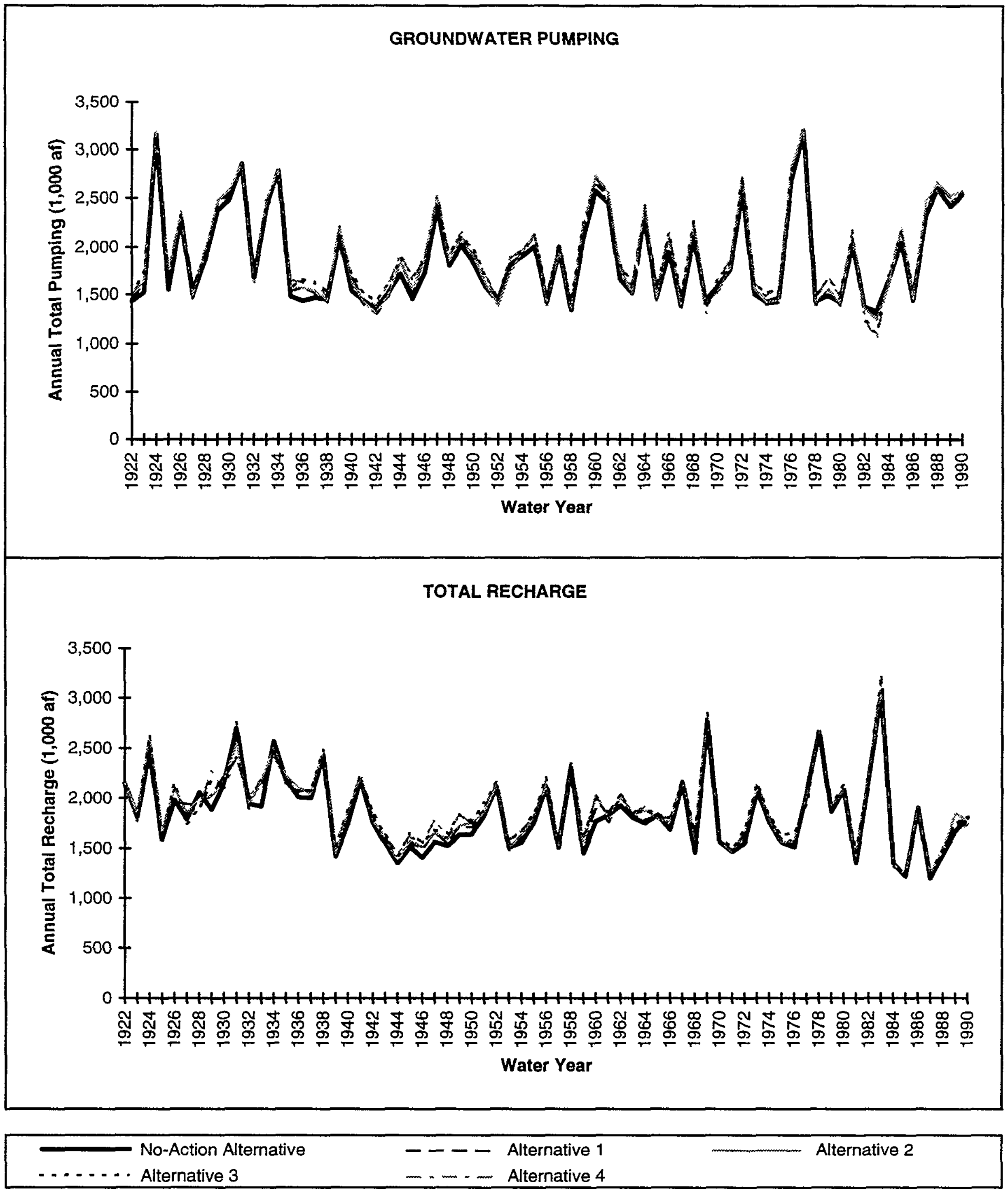
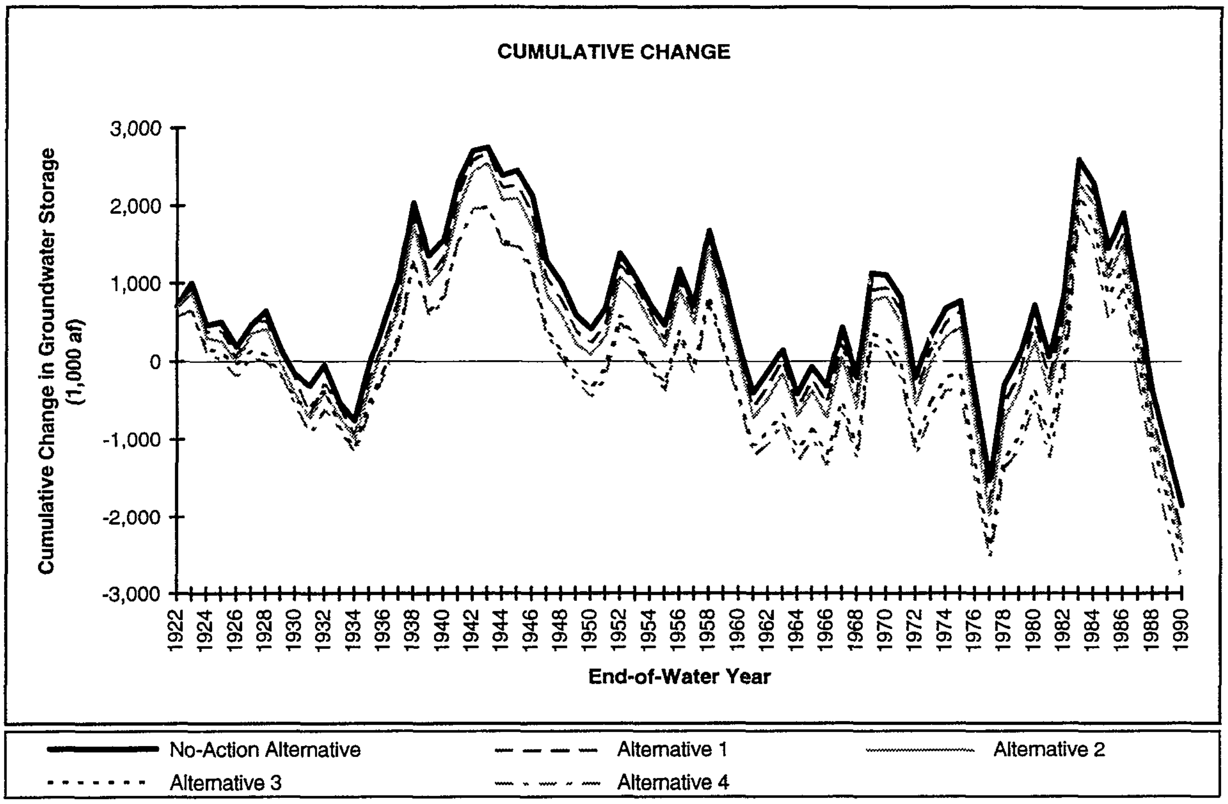


FIGURE III - 7
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SAN JOAQUIN RIVER REGION FOR ALTERNATIVES 1 THROUGH 4



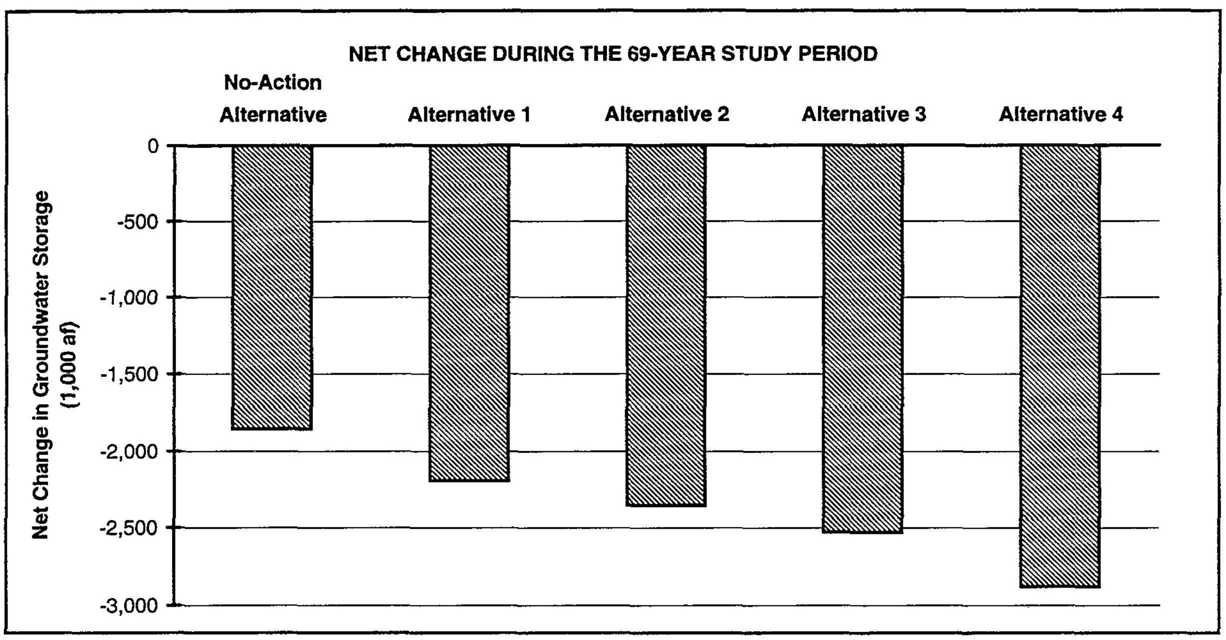


FIGURE III - 8
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SAN JOAQUIN RIVER REGION FOR ALTERNATIVES 1 THROUGH 4

Groundwater Quality

Groundwater quality, under the No-Action Alternative for the San Joaquin River Region, would be similar to recent historical conditions.

Agricultural Subsurface Drainage

Agricultural subsurface drainage problems under the No-Action Alternative, known to exist along the west side of the San Joaquin River Region are expected to be similar to recent historical conditions. Drainage problems may be alleviated somewhat by regional groundwater level declines along the west side of the southern portion of the region.

Seepage and Waterlogging

Under the No-Action Alternative, underlying groundwater levels in the area of the lower San Joaquin River and in the vicinity of its confluences with major tributaries are similar to, or lower than, recent historical conditions. In addition, average streamflows in this area similar to or lower than recent historical conditions, and seepage-induced waterlogging problems would be similar to recent historical conditions.

TULARE LAKE REGION

Groundwater Storage and Production

Tulare Lake Region (North). Average annual groundwater conditions for the Tulare Lake Region (North) under the No-Action Alternative are presented in Table III-4. Annual groundwater pumping averaged 4,043,000 acre-feet per year, ranging from approximately 2,200,000 acre-feet per year to 6,400,000 acre-feet per year. There are 4 years with pumping greater than 6,000,000 acre-feet per year and 16 more years with pumping above 5,000,000 acre-feet per year. This area of the Tulare Lake Region is dependent upon imported surface water supplies, and in some subregions there are no local surface water supplies. As these imported supplies fluctuate, groundwater pumping is relied upon to make up unmet water demands. Annual groundwater recharge (total) in the Tulare Lake Region (North) averaged 3,799,000 acre-feet per year, ranging from approximately 3,000,000 acre-feet per year to 4,800,000 acre-feet per year. The year-to-year variation in annual groundwater pumping and recharge are shown in Figure III-9. The change in groundwater storage in the Tulare Lake Region (North) is shown in Figure III-10. Relative to starting conditions, groundwater storage proceeded to decline over the course of the simulation period. The net change in groundwater storage over the 69-year simulation period is -16,790,000 acre-feet.

Tulare Lake Region (South). Average annual groundwater conditions for the Tulare Lake Region (South) under the No-Action Alternative are presented in Table III-5. Annual groundwater pumping averaged 1,411,000 acre-feet per year, ranging from approximately 700,000 acre-feet per year to 2,500,000 acre-feet per year. This area depends on numerous surface water supplies, including local supplies and imported supplies delivered by the CVP and SWP. As in other areas dependent upon imported supplies, fluctuations in annual groundwater pumping are frequent.

TABLE III-4

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE TULARE LAKE REGION (NORTH) (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	1,696	1,655	1,658	1,674	1,652	-41	-38	-23	-44
Gain from Streams	500	507	510	498	514	7	10	-1	15
Recharge (3)	396	417	418	405	421	21	22	10	25
Boundary Inflows (4)	1,208	1,254	1,258	1,224	1,259	47	50	17	51
Total Recharge	**3,799**	**3,833**	**3,844**	**3,802**	**3,846**	**34**	**44**	**2**	**47**
Discharge									
Groundwater Pumping	4,043	4,129	4,145	4,057	4,162	86	102	14	119
Total Discharge	**4,043**	**4,129**	**4,145**	**4,057**	**4,162**	**86**	**102**	**14**	**119**
Change in Groundwater Storage (5)	**-243**	**-296**	**-301**	**-255**	**-316**	**-52**	**-58**	**-12**	**-72**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

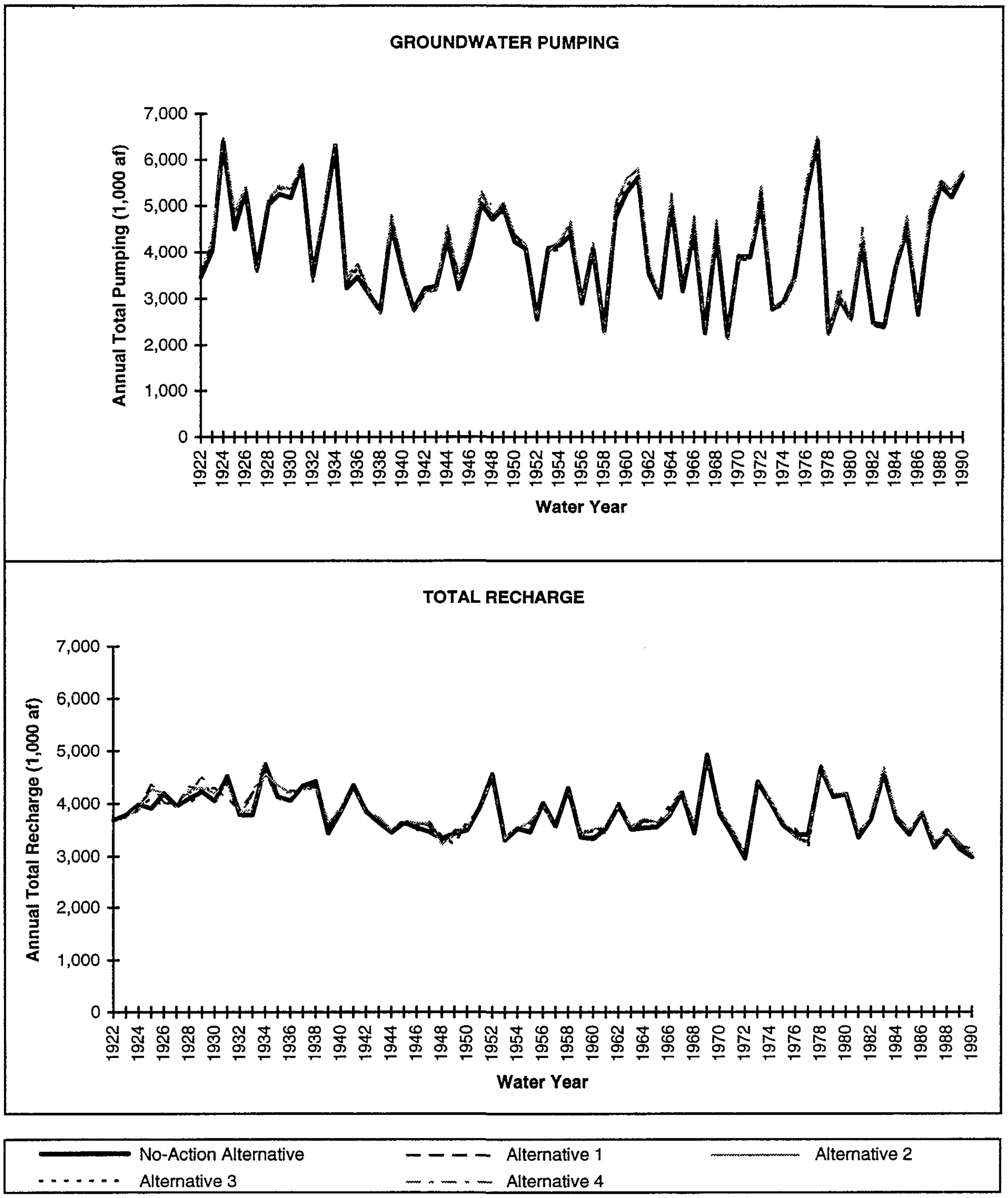
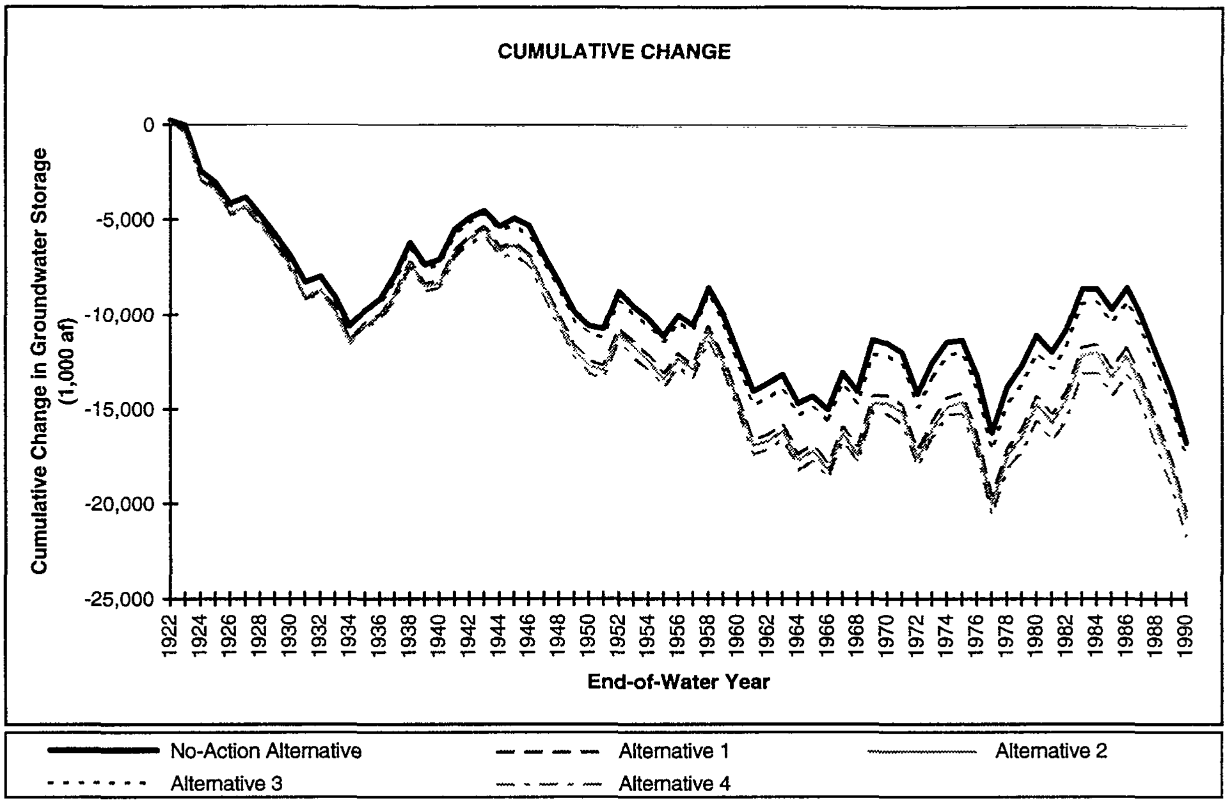


FIGURE III - 9
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE TULARE LAKE REGION (NORTH) FOR ALTERNATIVES 1 THROUGH 4



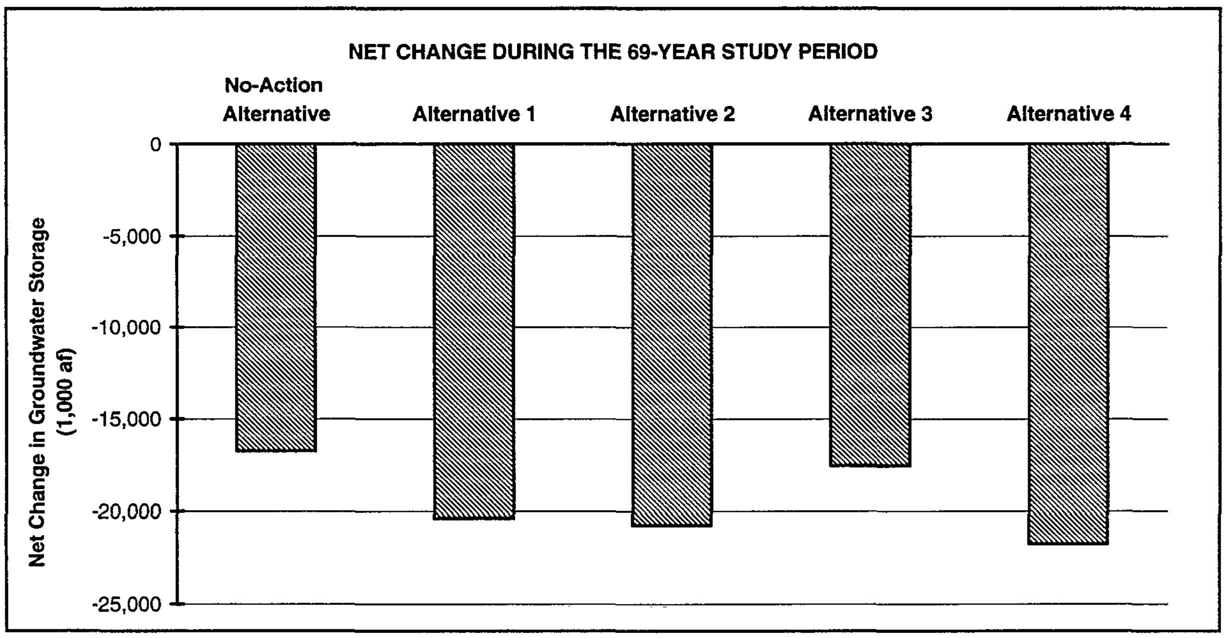


FIGURE III - 10
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE TULARE LAKE REGION (NORTH) FOR ALTERNATIVES 1 THROUGH 4

TABLE III-5

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE TULARE LAKE REGION (SOUTH) (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	958	964	974	979	968	6	16	22	11
Gain from Streams	225	216	212	195	217	-8	-13	-30	-8
Recharge (3)	124	120	119	112	120	-4	-6	-12	-4
Boundary Inflows (4)	222	213	214	204	216	-9	-8	-18	-6
Total Recharge	**1,529**	**1,513**	**1,518**	**1,490**	**1,521**	**-15**	**-11**	**-38**	**-7**
Discharge									
Groundwater Pumping	1,411	1,380	1,384	1,337	1,395	-31	-27	-74	-16
Total Discharge	**1,411**	**1,380**	**1,384**	**1,337**	**1,395**	**-31**	**-27**	**-74**	**-16**
Change in Groundwater Storage (5)	**118**	**133**	**134**	**153**	**127**	**16**	**16**	**35**	**9**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

Year-to-year variations in annual groundwater pumping and recharge are shown in Figure III-11. Annual groundwater recharge (total) averaged 1,529,000 acre-feet per year, ranging from approximately 1,000,000 acre-feet per year to 2,250,000 acre-feet per year.

The change in groundwater storage, shown in Figure III-12, indicates a long-term increase in groundwater storage. The net change in groundwater storage over the 69-year simulation period is 8,127,000 acre-feet. This outcome is attributable to the conditions and assumptions employed under the No-Action Alternative, which diminish the burden placed on groundwater pumping in this area in comparison to more recent historical conditions. There are several reasons for this: (1) the No-Action Alternative land use and demand conditions reflect improved irrigation efficiencies as a result of long-term conservation measures, retirement of lands on the west side of the region where very poor drainage conditions exist, and very minor changes on a regional scale in total irrigated agricultural land use in this area in comparison to recent historical conditions, and (2) in wet and above normal precipitation years and most normal precipitation years, this area receives its full entitlement of SWP supplies. This is an increase in imported surface water supplies above amounts received under recent historical conditions. This set of factors results in a general decrease in demand for groundwater pumping. This storage response is consistent with findings of DWR 2020 planning studies which suggest that with a full SWP entitlement in place, future groundwater use in this area could decrease under projected level land use conditions, reducing the areas long-term groundwater overdraft condition (DWR, 1994).

Groundwater Levels

Groundwater levels under the No-Action Alternative at the end of the 69-year simulation period are shown in Figure III-6c for the Tulare Lake Region (in feet above mean sea level). These levels represent the average of the upper semi-confined aquifer and the lower aquifer which is generally confined by the Corcoran Clay on the west side of this region. In the northern half of the Tulare Lake Region, in Fresno and Kings counties, groundwater levels decline from the valley rim towards depressed groundwater levels southwest of the City of Fresno. This large depression area is associated with an average annual groundwater storage decline of -243,000 acre-feet per year, the largest storage decline of the five regions reported for the No-Action Alternative. Groundwater levels in the southern half of the Tulare Lake Region are highest along the valley rim and decline from the east and west side in a northerly direction toward the valley axis. Portions of east side streams are hydraulically disconnected from underlying groundwater tables under recent conditions. From Madera County south to the Tulare-Kern County boundary, groundwater levels are lower in comparison to recent historical conditions, increasing the extent of this hydraulic disconnection.

Where confined conditions of layer 2 exist, simulated groundwater levels (piezometric head) may show a greater long-term decline in comparison to declines reported as layer 1 and 2 averaged groundwater levels. For areas along the west side, regional differences in layer 2 groundwater levels for the No-Action Alternative are up to 45 feet more than differences for layer 1 and 2 combined.

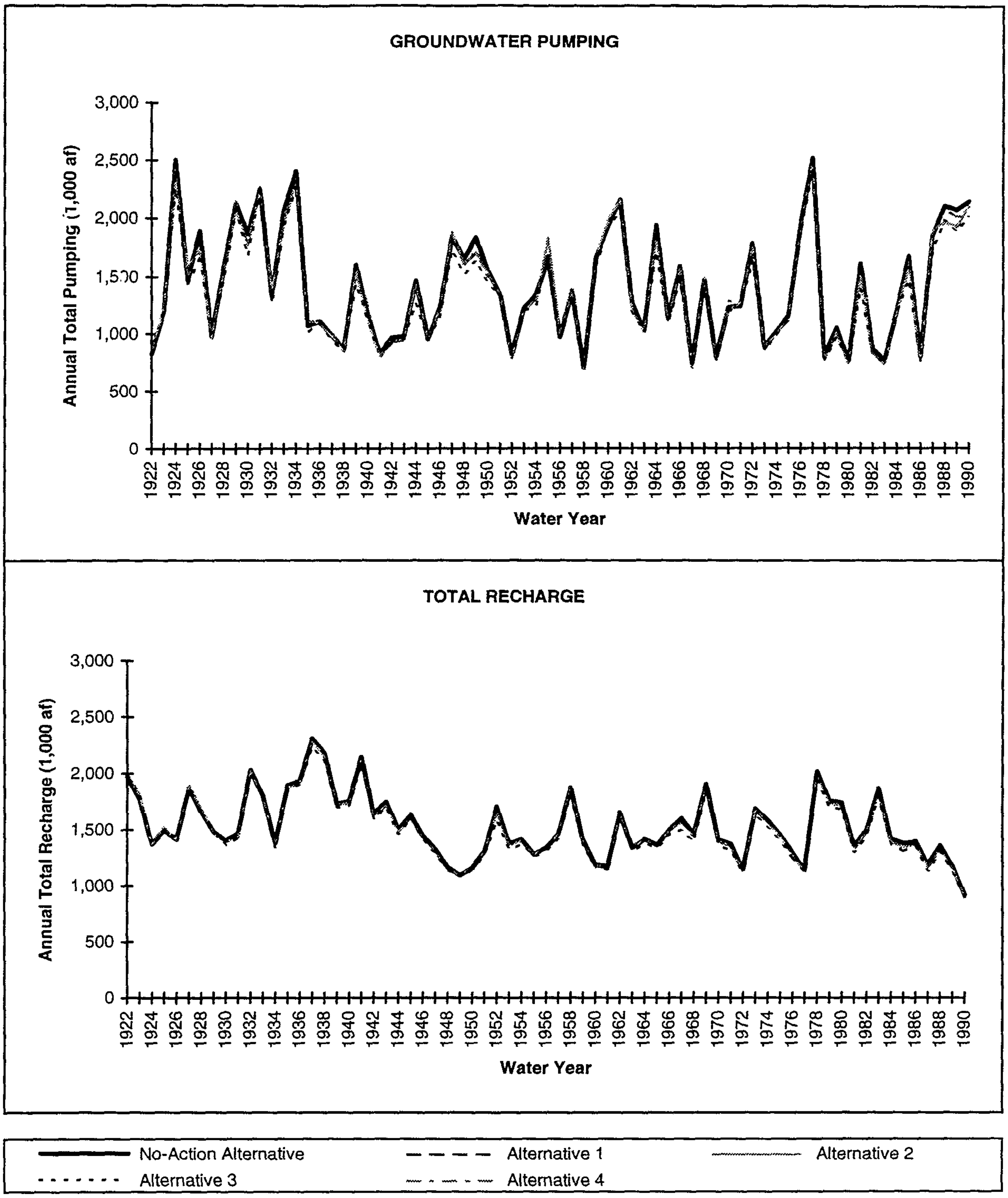


FIGURE III -11
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE TULARE LAKE REGION (SOUTH) FOR ALTERNATIVES 1 THROUGH 4

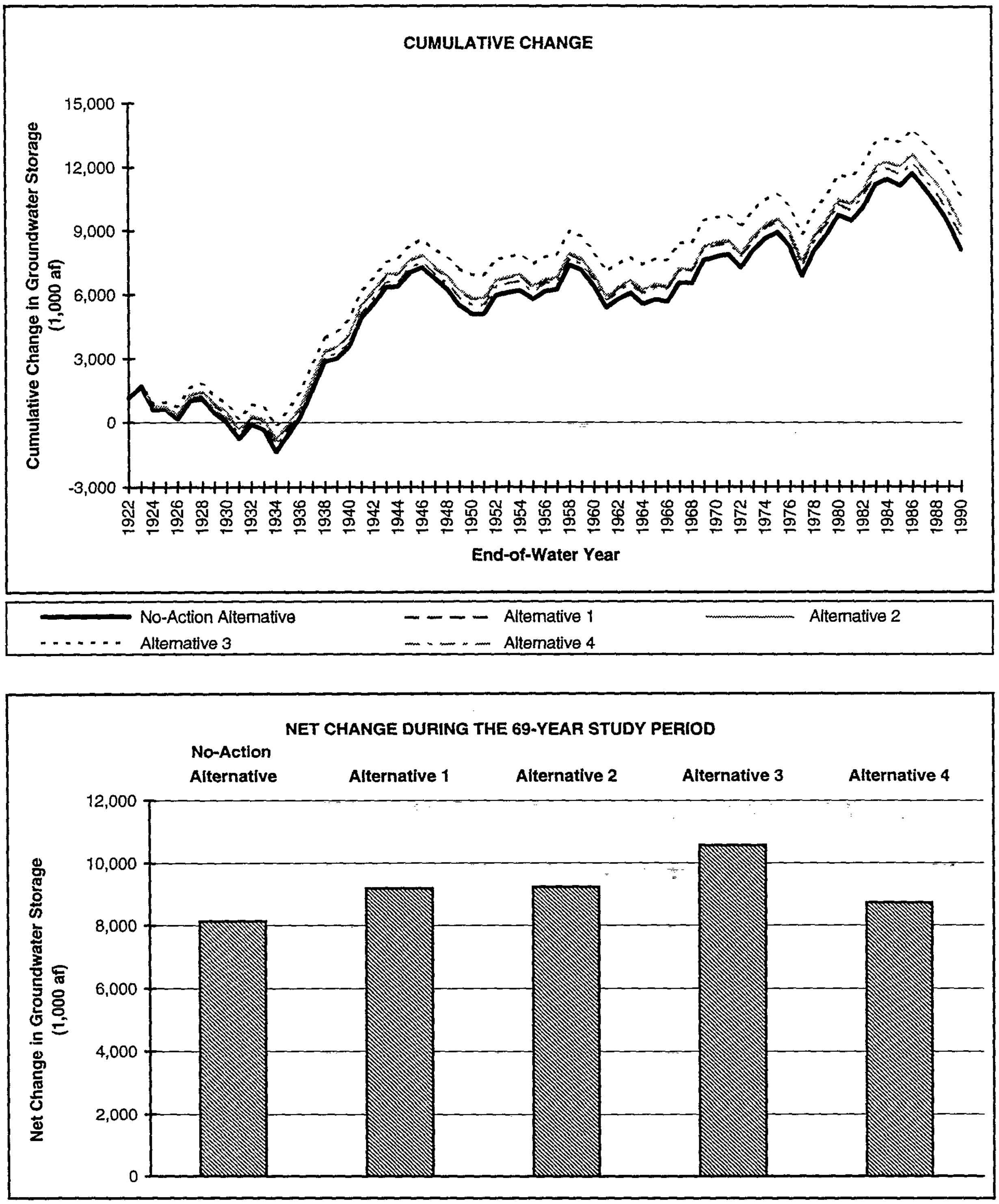


FIGURE III - 12
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE TULARE LAKE REGION (SOUTH) FOR ALTERNATIVES 1 THROUGH 4

Land Subsidence

Land subsidence is known to occur in the area along the west side of the Tulare Lake Region as well as the southwestern portion of Tulare County and the southern end of Kern County. For the No-Action Alternative, increased land subsidence in this area would likely occur relative to recent historical conditions.

Groundwater Quality

Groundwater quality under the No-Action Alternative would most likely be degraded due to the induced migration of groundwater with high TDS levels along the west side into the depressed groundwater levels in the mid-valley area, and possible upwelling of saline groundwater into productive groundwater zones. Groundwater contaminated with dibromochloropropane in eastern Fresno County could also be mobilized towards these depressed groundwater level areas.

Agricultural Subsurface Drainage

Agricultural subsurface drainage problems under the No-Action Alternative, known to exist along the west side of the Tulare Lake Region, are expected to be similar to recent historical conditions. As in the San Joaquin River Region, groundwater level declines along the west side of the Tulare Lake Region could result in improved drainage. However, increases in groundwater levels in the southern end of the Tulare Lake Region could possibly hinder agricultural subsurface drainage in areas of poorly drained soils.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with streamflows and adjacent high groundwater tables in the Tulare Lake Region.

SAN FRANCISCO BAY REGION

Groundwater resources of the San Francisco Bay Region are addressed qualitatively for areas receiving CVP water. For the purposes of this analysis, present groundwater conditions described in Chapter II are used as a frame of reference for determining potential impacts due to changes in CVP deliveries.

Groundwater resources in Santa Clara and San Benito counties are managed to minimize groundwater overdraft, land subsidence, and groundwater quality degradation. This task is facilitated by CVP project water imports via the San Felipe Division. Groundwater resources in parts of Alameda and Contra Costa counties are limited, have poor water quality, and can suffer from groundwater overdraft and land subsidence in the absence of alternative supplies. The continued importation of CVP project water supplements these limited supplies and reduces the likelihood of further groundwater-related impacts.

ALTERNATIVE 1

Water management provisions in Alternative 1 were developed to utilize two of the tools provided by CVPIA, Re-operation and 3406(b)(2) Water Management for purposes of meeting instream flow requirements for CVP-controlled streams. A number of key features and assumptions distinguish Alternative 1 from the No-Action Alternative. The features discussed here are limited to those having the greatest effect on groundwater resources in the study area.

Surface Water Diversions for agricultural users relying on CVP-controlled streams are reduced in comparison to the No-Action Alternative as a result of the water management actions assumed under Alternative 1. The CVP reductions occur primarily along the west side of the San Joaquin River and Tulare Lake regions and are associated with the Delta Mendota Service Area and the San Luis Unit Service Area. Small reductions in CVP deliveries in the Sacramento River Region occur, affecting primarily the west side. SWP supplies increase on average in comparison to the No-Action Alternative. The increase in SWP agricultural deliveries relative to the No-Action Alternative would occur in the Tulare Lake Region.

Refuge Supplies increase from No-Action Alternative as a result of provisions for a firm Level 2 water supply.

Land Use changes occur as a result of land retirement and fallowing. Land retirement of an additional 30,000 acres above the No-Action Alternative is assumed, in order to implement the SJVDP recommendations. The distribution of these additional retired lands by region is expected to be:

- 1,200 acres in the San Joaquin River Region
- 17,200 acres in the Tulare Lake Region (North)
- 11,600 acres in the Tulare Lake Region (South)

Additional reductions in agricultural crop acreage may occur as a result of land fallowing in response to reduced CVP deliveries (see the agricultural economics analysis).

Groundwater Pumping is assumed to replace reductions in CVP deliveries to the extent that increased pumping is economically feasible. A reduction in groundwater pumping occurs in areas where land retirement and fallowing occurs, and areas with increased SWP deliveries.

SACRAMENTO RIVER REGION

The differences between Alternative 1 and the No-Action Alternative in groundwater levels at the end of the 69-year simulation are shown in Figure III-13a. Long-term regional groundwater conditions in the Sacramento River Region would be similar to conditions under the No-Action Alternative, with the exception of several isolated cases. These differences would occur in response to reduced CVP deliveries relative to the No-Action Alternative, and are discussed further below.

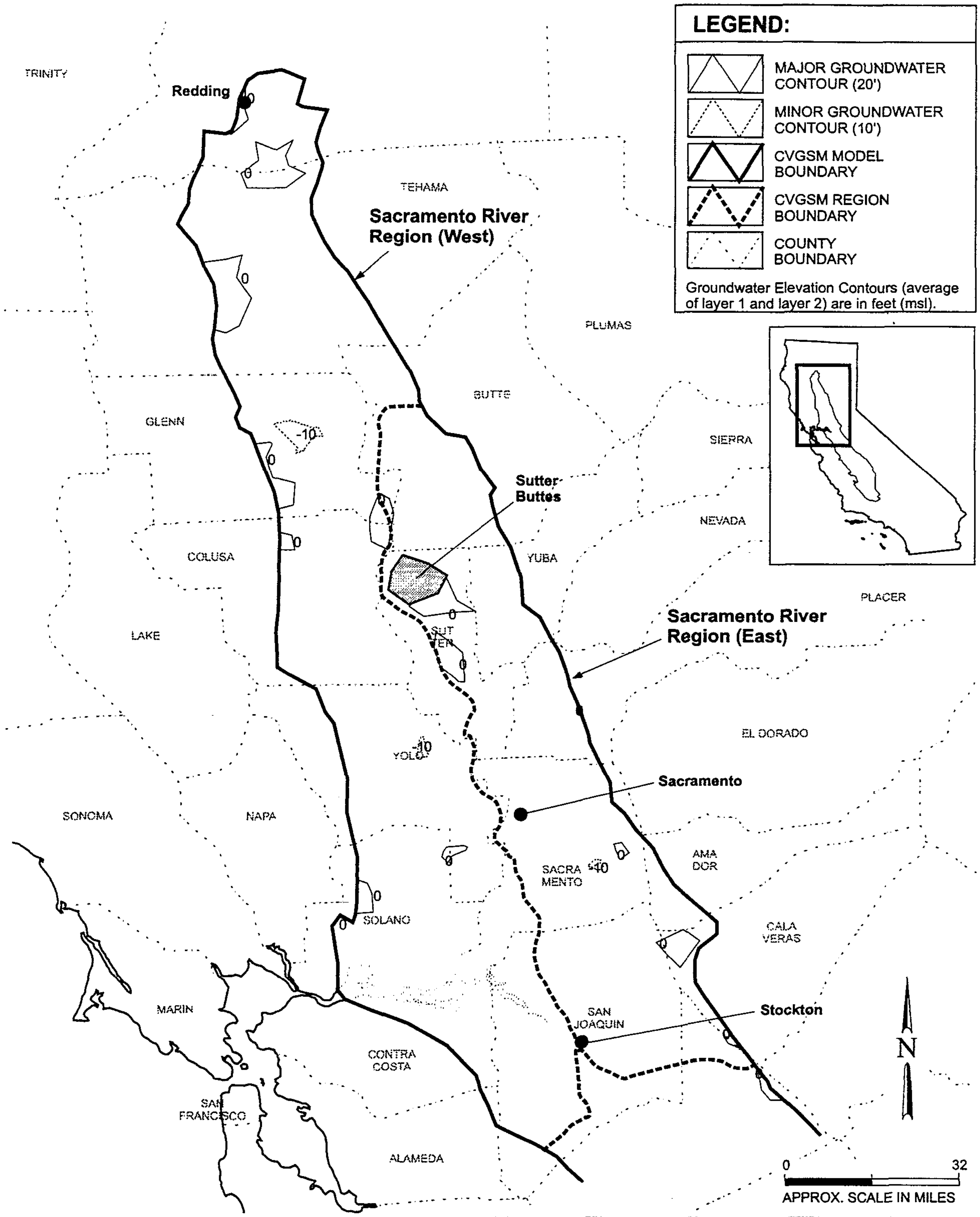


FIGURE III-13a
SACRAMENTO RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 1 AS COMPARED TO THE NO-ACTION ALTERNATIVE

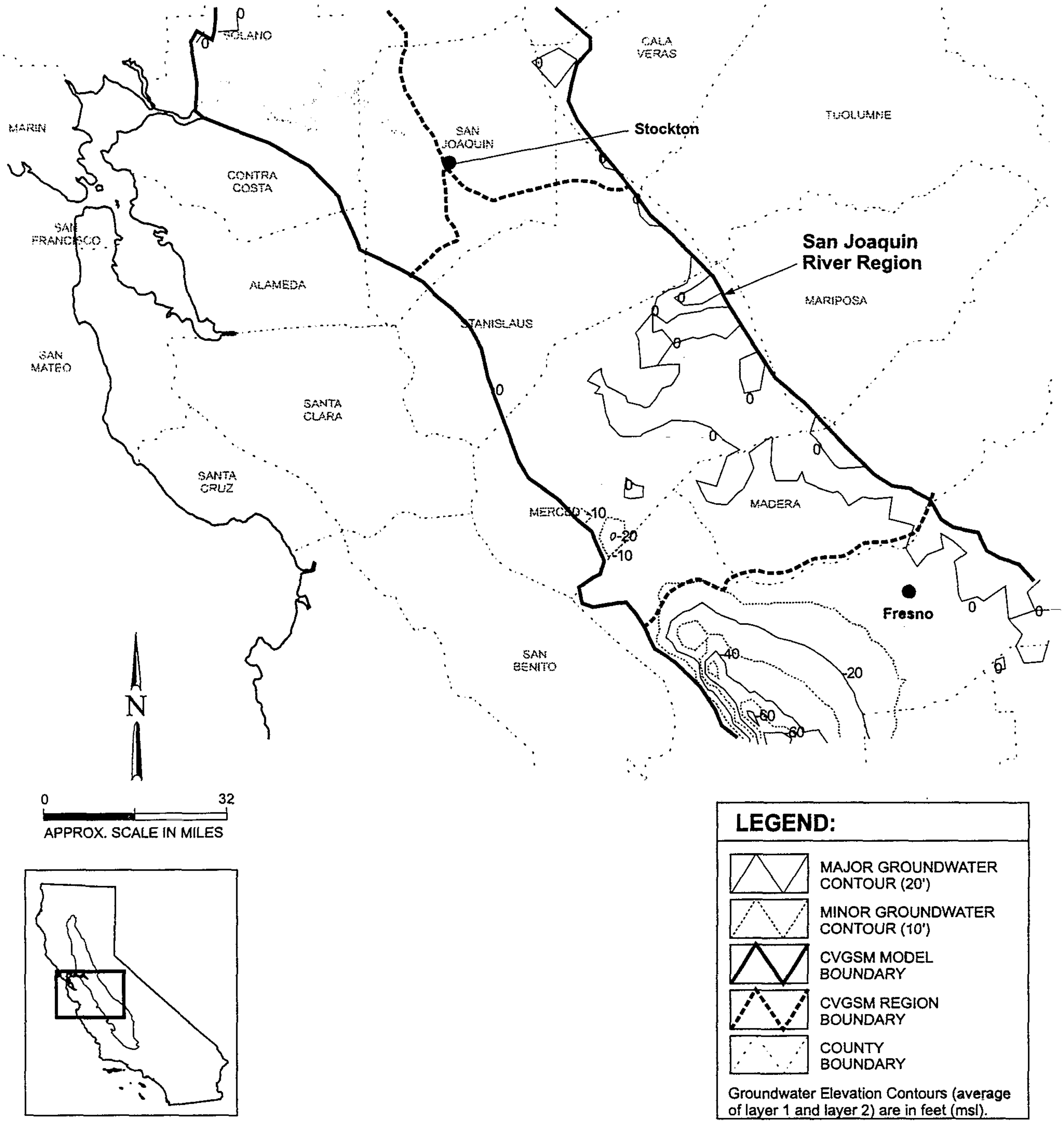


FIGURE III-13b
SAN JOAQUIN RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 1 AS COMPARED TO THE NO-ACTION ALTERNATIVE

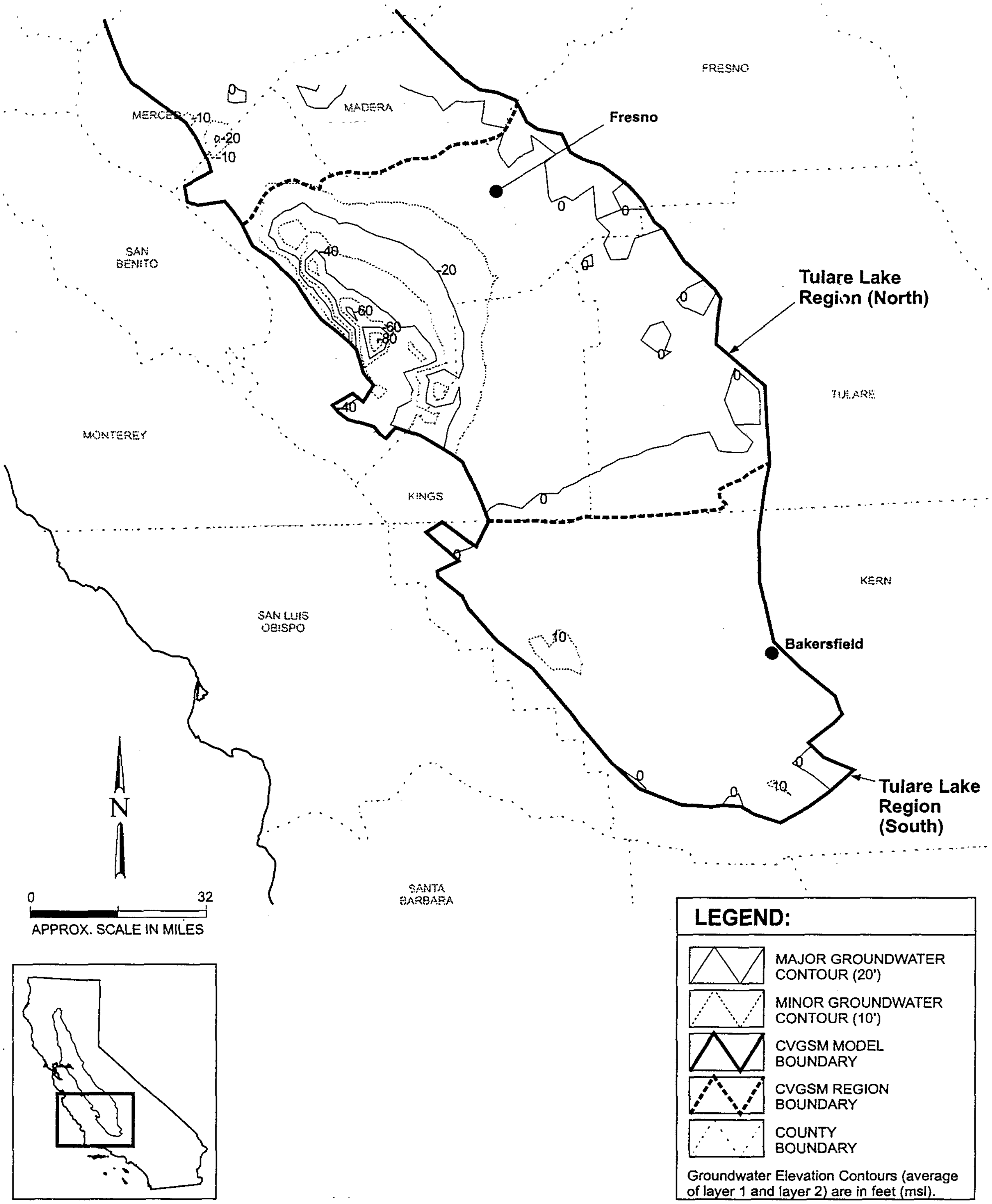


FIGURE III-13c
TULARE LAKE REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 1 AS COMPARED TO THE NO-ACTION ALTERNATIVE

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Groundwater Storage and Production

Sacramento River Region (West). Average annual groundwater conditions for the Sacramento River Region (West) under Alternative 1 are presented in Table III-1. Annual groundwater pumping averaged 2,076,000 acre-feet per year, or approximately 38,000 acre-feet per year more than under the No-Action Alternative. Increases in annual groundwater pumping for Alternative 1 occurred primarily in years of dry or critically dry hydrologic conditions. This increase in pumping is a direct response to reductions in CVP deliveries to this area. Annual groundwater recharge (total) averaged 2,066,000 acre-feet per year, or 32,000 acre-feet per year more than under the No-Action Alternative. Relative to the No-Action Alternative, recharge increased due to a 1 percent increase in deep percolation (caused by increased refuge deliveries to the area) and a 5 percent increase in stream losses (caused by a decline in groundwater levels). The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative.

The change in groundwater storage in the Sacramento River Region (West) for Alternative 1 is shown in Figure III-3. In comparison to the No-Action Alternative, groundwater storage followed the same general pattern. Groundwater reserves were depleted more during dry to critically dry periods than the No-Action Alternative, as much as 400,000 acre-feet in simulation year 1934. However, groundwater storage for Alternative 1 returned to approximately the same condition by simulation year 1958. The net total change in groundwater storage over the 69-year simulation period is -683,000 acre-feet, or 353,000 acre-feet more groundwater depletion than the No-Action Alternative.

Sacramento River Region (East). Average annual groundwater conditions for the Sacramento River Region (East) under Alternative 1 are presented in Table III-2. Annual groundwater pumping averaged 1,817,000 acre-feet per year, or approximately 32,000 acre-feet per year more than under the No-Action Alternative. Increases in annual groundwater pumping for Alternative 1 occurred uniformly throughout the simulation period. This increase in pumping is a direct response to reductions in CVP deliveries to this area. Annual groundwater recharge (total) averaged 1,753,000 acre-feet per year, or 28,000 acre-feet per year more than under the No-Action Alternative. Relative to the No-Action Alternative, recharge increased due to a 1 percent increase in deep percolation, and a 3 percent increase in stream losses (caused by a decline in groundwater levels). The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative.

The change in groundwater storage in the Sacramento River Region (East) for Alternative 1 is shown in Figure III-5. In comparison to the No-Action Alternative, groundwater storage followed the same general pattern. The net total change in groundwater storage over the 69-year simulation period is -4,416,000 acre-feet, or 251,000 acre-feet more groundwater depletion than the No-Action Alternative.

Groundwater Levels

From a regional perspective, groundwater levels are the same as the No-Action Alternative. In several specific areas along the west side and some areas north and northeast of the Delta, groundwater levels would be lower by approximately 10 feet (Figure III-13a). Groundwater level differences occurred in the northern Tehama Colusa Canal service area, the Yolo County area, and the Sacramento County area. On a regional basis, the hydraulic connection between streams and underlying groundwater tables is similar to the No-Action Alternative.

Land Subsidence

Under Alternative 1, with groundwater levels declining very little in this area, no additional land subsidence in comparison to the No-Action Alternative would occur.

Groundwater Quality

Under Alternative 1, with groundwater levels declining very little in this area, groundwater quality would be similar to the No-Action Alternative.

Agricultural Subsurface Drainage

Under Alternative 1, with groundwater levels declining very little in this area, agricultural subsurface drainage problems in the Sacramento River Region would not change in comparison to the No-Action Alternative.

Seepage and Waterlogging

Exceedence diagrams comparing summer flows in three reaches of the Sacramento River under Alternative 1 with those for the No-Action Alternative are shown in Figure III-14. The difference between summer flow distributions under the No-Action Alternative and Alternative 1 are minor, and generally indicate slightly lower summer flows under Alternative 1 than in the No-Action Alternative. In addition, groundwater levels in the vicinity of these stream reaches would not increase in comparison to the No-Action Alternative. Seepage-induced waterlogging of low-lying farm lands adjacent to the Sacramento River would not change for Alternative 1 as compared to the No-Action Alternative.

SAN JOAQUIN RIVER REGION

Differences in groundwater levels at the end of the 69-year simulation period between Alternative 1 and the No-Action Alternative for the San Joaquin River Region are shown in Figure III-13b. Long-term groundwater conditions in this region under Alternative 1 would be similar to the No-Action Alternative on a regional basis.

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under Alternative 1 are presented in Table III-3. Annual groundwater pumping averaged 1,915,000 acre-feet per year, or approximately 40,000 acre-feet per year more than under the No-Action Alternative. Annual groundwater recharge (total) averaged 1,883,000 acre-feet per year, or 35,000 acre-feet per year more than under the No-Action Alternative. Relative to the No-Action Alternative, recharge increased due to a slight increase in deep percolation (caused by increased refuge deliveries to the area) and seepage from canals, and a 7 percent increase in stream losses (caused by a decline in

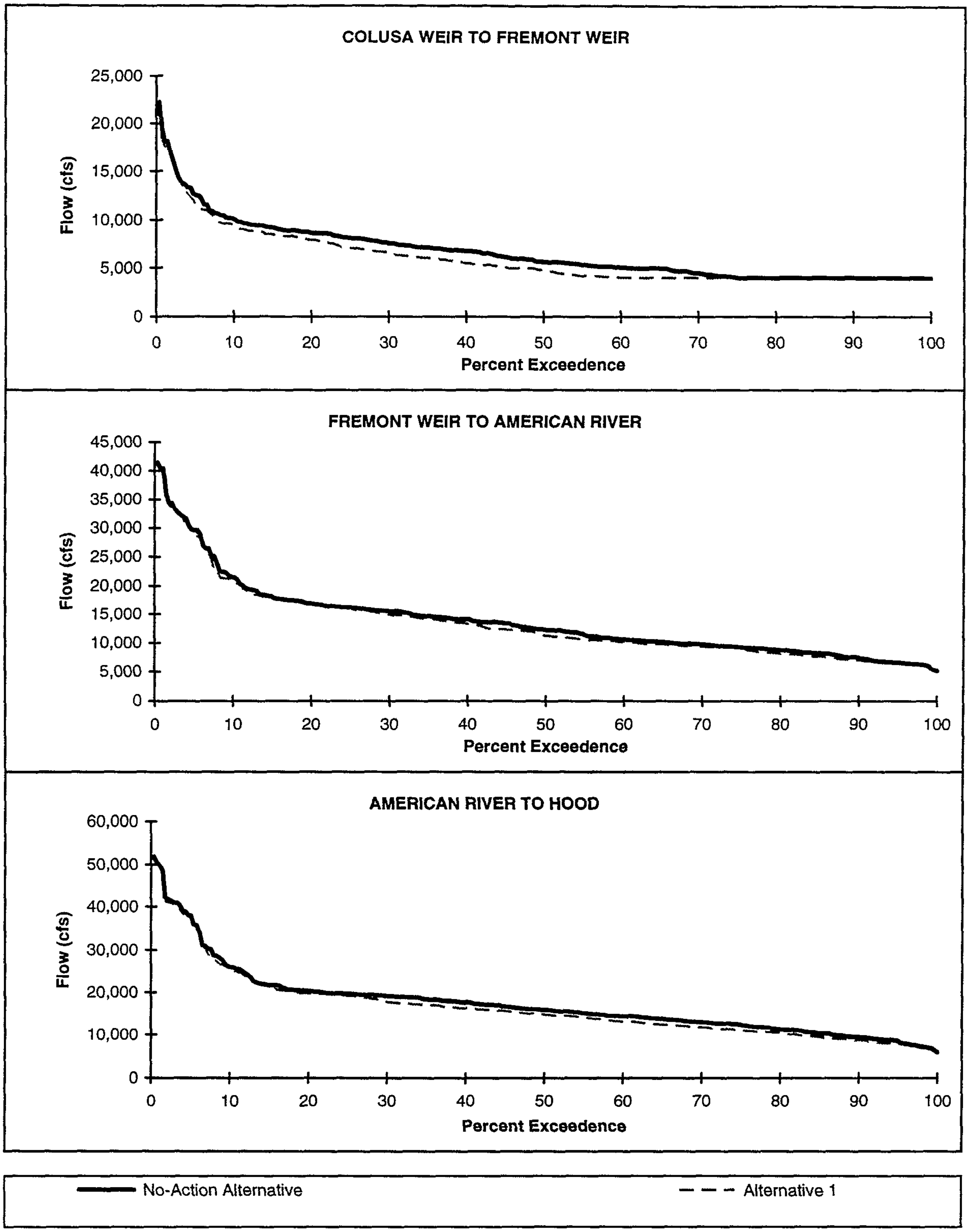


FIGURE III-14
SIMULATED SACRAMENTO RIVER FLOWS (MAY THROUGH AUGUST) FOR ALTERNATIVE 1 AS COMPARED TO NO-ACTION ALTERNATIVE

groundwater levels). The annual variation in groundwater pumping and recharge shown in Figure III-7 is very similar to the No-Action Alternative.

The change in groundwater storage shown in Figure III-8 for the San Joaquin River Region, in comparison to the No-Action Alternative, followed the same general pattern. The net change in groundwater storage over the 69-year simulation period is -2,199,000 acre-feet, or 340,000 acre-feet more groundwater depletion than the No-Action Alternative.

Groundwater Levels

Differences in groundwater levels under Alternative 1 from the No-Action Alternative for the end of the 69-year simulation period are shown in Figure III-13b (in feet above mean sea level). From a regional perspective, groundwater levels in the north half of the region are the same as the No-Action Alternative. In the southwestern corner (the DMC service area) groundwater levels are lower by approximately 10 to 20 feet. These differences would occur in response to reduced CVP project deliveries relative to the No-Action Alternative. On a regional basis under Alternative 1 the hydraulic connection between streams and underlying groundwater tables is similar to the No-Action Alternative.

Land Subsidence

For Alternative 1 the range of differences in simulated land subsidence are provided in Figure III-15. Over the 69-year simulation period, land subsidence of 1 to 5 feet would occur under Alternative 1 in the southwestern portion of the region. This is a result of groundwater level declines occurring in this area. The area of land subsidence surrounds major conveyance facilities including the DMC and the California Aqueduct.

Groundwater Quality

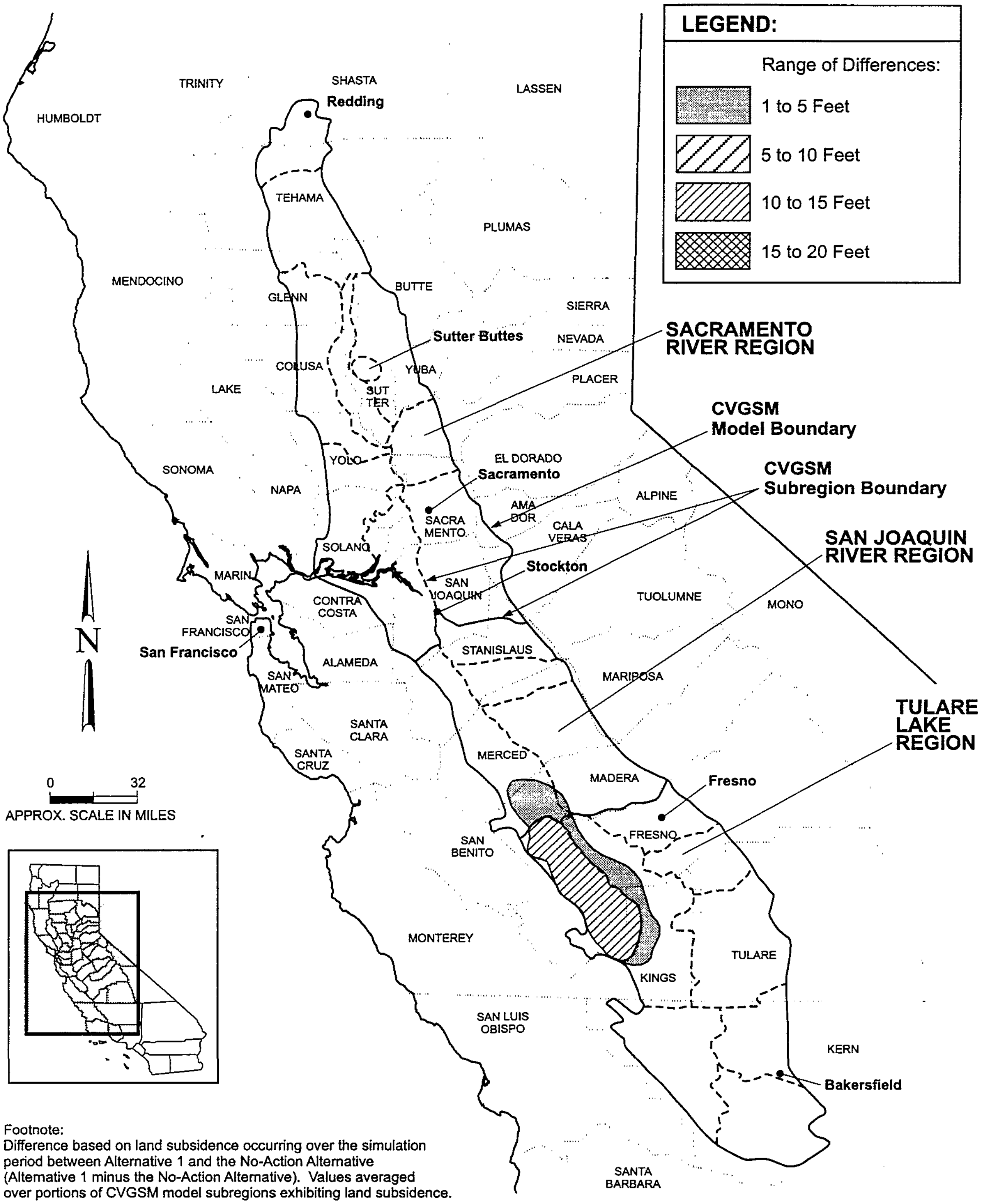
Under Alternative 1, it is expected that regional groundwater quality in the San Joaquin River Region would not change in comparison to the No-Action Alternative.

Agricultural Subsurface Drainage

Agricultural subsurface drainage conditions in the San Joaquin River Region would improve relative to the No-Action Alternative as a result of land retirement of approximately 1,200 acres in areas of poorly drained soils.

Seepage and Waterlogging

Figure III-16 shows a comparison of exceedence levels for summer flows in the San Joaquin River at Vernalis under Alternative 1 and the No-Action Alternative. There is no discernible difference at the 14,000 cfs flow level, and groundwater levels in this area would not increase as compared to the No-Action Alternative. Based on this information, seepage-induced waterlogging problems on farm lands along the lower reaches of the San Joaquin River and its tributaries would not change from the No-Action Alternative.



Footnote:
Difference based on land subsidence occurring over the simulation period between Alternative 1 and the No-Action Alternative (Alternative 1 minus the No-Action Alternative). Values averaged over portions of CVGSM model subregions exhibiting land subsidence.

FIGURE III-15

REGIONAL DIFFERENCES IN SIMULATED LAND SUBSIDENCE IN ALTERNATIVE 1 FROM NO-ACTION ALTERNATIVE

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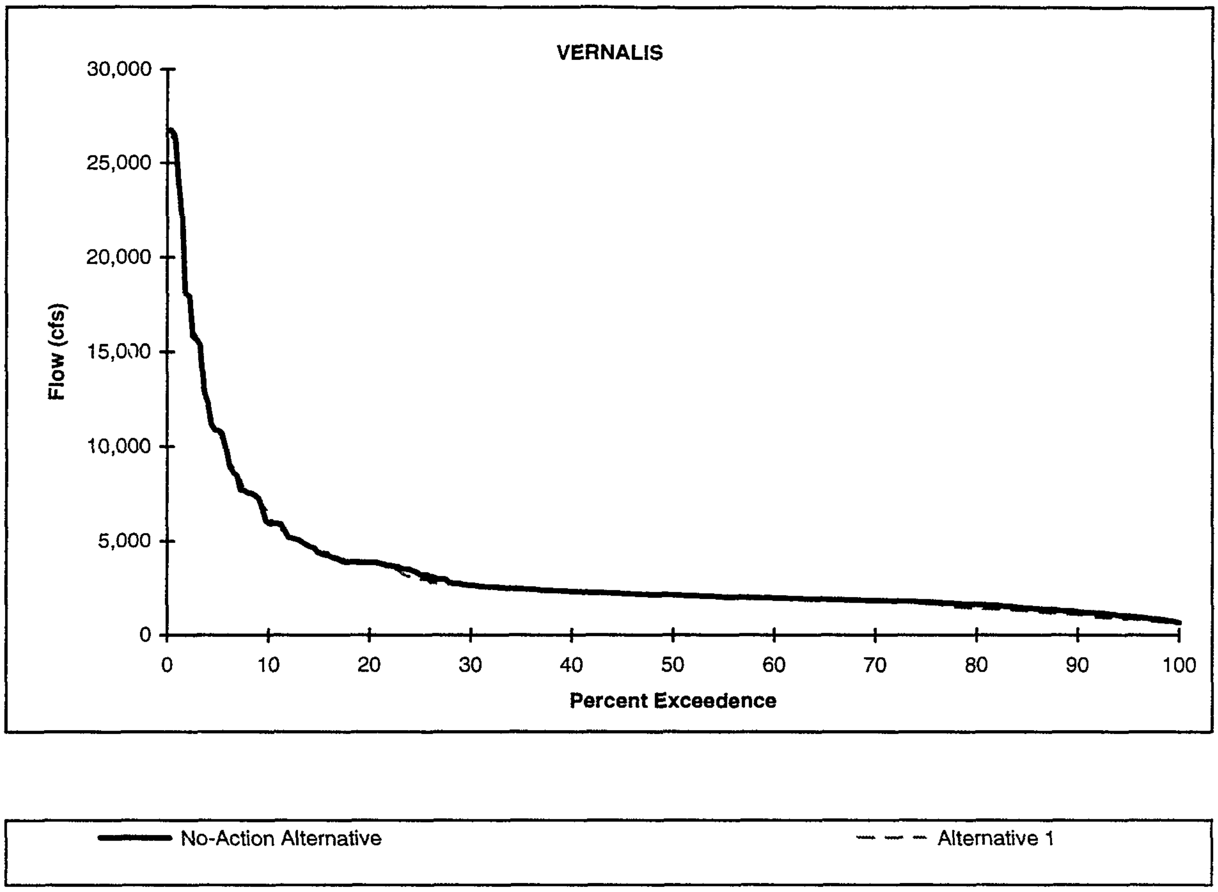


FIGURE III-16
SIMULATED SAN JOAQUIN RIVER FLOWS (MAY THROUGH AUGUST) FOR ALTERNATIVE 1 AS COMPARED TO NO-ACTION ALTERNATIVE

TULARE LAKE REGION

Groundwater levels for Alternative 1 would be lower in comparison to the No-Action Alternative along the west side of the Tulare Lake Region (Figure III-13c), particularly in the northern portion of this region where differences exceeded 80 feet at the end of the 69-year simulation period.

Groundwater Storage and Production

Tulare Lake Region (North). Average annual groundwater conditions for the Tulare Lake Region (North) under Alternative 1 are presented in Table III-4. Annual groundwater pumping averaged 4,129,000 acre-feet per year, or 86,000 acre-feet per year more than under the No-Action Alternative. Groundwater pumping for Alternative 1 was the same or larger than No-Action pumping throughout the 69-year simulation period (Figure III-9). Increases in groundwater pumping are in response to changing CVP deliveries to this area, which are reduced in comparison to the No-Action Alternative as a result of the (b)(2) water management. This increase would be partially offset by decreased groundwater pumping in areas with land retirement. Total land retirement in the Tulare Lake Region (North) is approximately 17,200 acres. Groundwater recharge (total) averaged 3,833,000 acre-feet per year, or 34,000 acre-feet per year more than under the No-Action Alternative. The recharge increased relative to the No Action Alternative, due to a 5 percent increase in seepage from canals and a 4 percent increase in subsurface flow from adjacent areas (caused by a decline in groundwater levels).

The change in groundwater storage for Alternative 1 is shown in Figure III-10. In comparison to the No-Action Alternative groundwater storage in this area under Alternative 1 followed the same general pattern of decline; the rate of decline is slightly higher in Alternative 1 in comparison to the No-Action Alternative. The net change in groundwater storage over the 69-year simulation period is approximately -20,406,000 acre-feet, or 3,616,000 acre-feet more groundwater depletion than the No-Action Alternative.

Tulare Lake Region (South). Average annual groundwater conditions for the Tulare Lake Region (South) under Alternative 1 are presented in Table III-5. Annual groundwater pumping averaged 1,380,000 acre-feet per year, or 31,000 acre-feet per year less than under the No-Action Alternative. This decrease in groundwater pumping is a result of additional SWP supplies becoming available and land retirement totaling 11,600 acres. Groundwater levels in this area generally increased slightly in comparison to the No-Action Alternative. Annual groundwater recharge (total) averaged 1,513,000 acre-feet per year, or 16,000 acre-feet per year less than under the No-Action Alternative. The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative (Figure III-11).

The change in groundwater storage in the Tulare Lake Region (South) for Alternative 1 is shown in Figure III-12. This figure indicates that in comparison to the No-Action Alternative groundwater storage in this area under Alternative 1 followed the same general pattern. The net total change in groundwater storage over the 69-year simulation period is 9,199,000 acre-feet, 1,072,000 acre-feet more in groundwater storage than the No-Action Alternative.

Groundwater Levels

Groundwater levels for Alternative 1 for the end of the 69-year simulation period are shown in Figure III-13c for the Tulare Lake Region (in feet above mean sea level). Groundwater levels are lower in Alternative 1 in comparison to the No-Action Alternative along the west side of the region, with differences exceeding 80 feet. This is primarily a result of increased groundwater pumping in response to reductions in imported surface water supplies from the CVP. There is little difference in groundwater levels along the east side of the Tulare Lake Region. Stream-groundwater interaction along the east side would be similar in comparison to the No-Action Alternative.

Where confined conditions of layer 2 exist, simulated groundwater levels (piezometric head) may show a greater long-term decline in comparison to declines reported as layer 1 and 2 averaged groundwater levels. For areas along the west side, regional differences in layer 2 groundwater levels between Alternative 1 and the No-Action Alternative are about 5 feet more than differences for layer 1 and 2 combined.

Land Subsidence

Additional groundwater level declines observed in Alternative 1 in comparison to the No-Action Alternative indicates that additional land subsidence would occur along the west side of the Tulare Lake Region (North). Figure III-15 shows the range of differences in land subsidence occurring over the simulation period between Alternative 1 and the No-Action Alternative (shown as Alternative 1 minus No-Action Alternative). The differences along the west side range between 10 and 15 feet. The range in differences decreases to 1 to 5 feet toward the axis of the Central Valley. The area of land subsidence surrounds major conveyance facilities including the DMC and the California Aqueduct.

Groundwater Quality

Along the west side of the region, average piezometric groundwater levels associated with the layer 3 aquifer below the pumping layer drop by 34 feet, possibly a result of upwelling in response to extensive pumping in layer 2. Under Alternative 1, the presence of these lower groundwater levels in relation to the No-Action Alternative could possibly cause additional upwelling of poor-quality groundwater into productive groundwater zones.

Agricultural Subsurface Drainage

Agricultural subsurface drainage problems would improve in comparison to the No-Action Alternative as a result of land retirement of approximately 28,800 acres in areas of poorly drained soils, and relative declines in groundwater levels.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with streamflows and adjacent high groundwater tables in the Tulare Lake Region, and none of the options associated with Alternative 1 would initiate any seepage problem in comparison to the No-Action Alternative.

SAN FRANCISCO BAY REGION

Under Alternative 1, CVP deliveries to Santa Clara and San Benito counties would decrease on average 18,000 acre-feet per year relative to the No-Action Alternative. Local regulation of groundwater extraction by means of pump taxes, such as those levied by the Santa Clara Valley Water District (SCVWD), would discourage replacement of this CVP water with groundwater. For the purposes of this programmatic level of analysis it is assumed that any increase in groundwater pumping to offset these reduced CVP deliveries would be minimal. A small impact to groundwater conditions could occur in the vicinity of spreading basins as a result of lost deep percolation associated with the reduced CVP deliveries.

Under Alternative 1 CVP deliveries to Alameda and Contra Costa counties would be similar to the No-Action Alternative. Under these conditions no net impact to groundwater storage, levels, and quality would occur, and no additional land subsidence would occur in these areas.

SUPPLEMENTAL ANALYSIS 1a

Supplemental Analysis 1a examines the incremental effects of using (b)(2) water to meet Delta outflow requirements, in addition to meeting instream flow requirements for CVP-controlled streams in Alternative 1. The implication for groundwater conditions is that (b)(2) water released for instream flow north of Delta cannot be pumped for south of Delta delivery. In the event this occurs, groundwater pumping would increase to replace reductions in these deliveries. All remaining assumptions underlying this analysis are the same as those for Alternative 1.

SACRAMENTO RIVER REGION

In general, regional groundwater conditions for Supplemental Analysis 1a in the Sacramento River Region are similar to Alternative 1. Average annual groundwater conditions for the Sacramento River Region under Supplemental Analysis 1a, as compared to the No-Action Alternative, are summarized in Tables III-6 and III-7. Annual groundwater conditions as compared to the No-Action Alternative are shown in Figures III-17, III-18, III-19, and III-20. Groundwater level differences in the Sacramento River Region for the end of the 69-year simulation for the Supplemental Analysis 1a as compared to the No-Action Alternative are shown in Figure III-21a.

SAN JOAQUIN RIVER REGION

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under Supplemental Analysis 1a are presented in Table III-8. Average annual groundwater conditions are similar to the No-Action Alternative, except for the southwestern portion (the DMC service area). This would occur as a result of CVP deliveries experiencing more frequent deficiencies under the

TABLE III-6

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SACRAMENTO RIVER REGION (WEST) (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compared to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	1,667	1,686	1,686	1,691	19	19	24
Gain from Streams	255	267	267	269	12	12	14
Recharge (3)	32	32	32	32	0	0	0
Boundary Inflows (4)	79	81	81	81	2	2	2
Total Recharge	**2,034**	**2,066**	**2,066**	**2,073**	**32**	**32**	**39**
Discharge							
Groundwater Pumping	2,038	2,076	2,076	2,083	37	37	45
Total Discharge	**2,038**	**2,076**	**2,076**	**2,083**	**37**	**37**	**45**
Change in Groundwater Storage (5)	**-5**	**-10**	**-10**	**-10**	**-5**	**-5**	**-6**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE III-7

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SACRAMENTO RIVER REGION (EAST) (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compared to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	819	828	828	828	9	9	9
Gain from Streams	516	528	528	528	13	13	13
Recharge (3)	24	24	24	24	0	0	0
Boundary Inflows (4)	366	372	372	372	6	6	6
Total Recharge	**1,725**	**1,753**	**1,753**	**1,753**	**28**	**28**	**28**
Discharge							
Groundwater Pumping	1,785	1,817	1,817	1,817	32	31	32
Total Discharge	**1,785**	**1,817**	**1,817**	**1,817**	**32**	**31**	**32**
Change in Groundwater Storage (5)	**-60**	**-64**	**-64**	**-64**	**-4**	**-4**	**-4**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

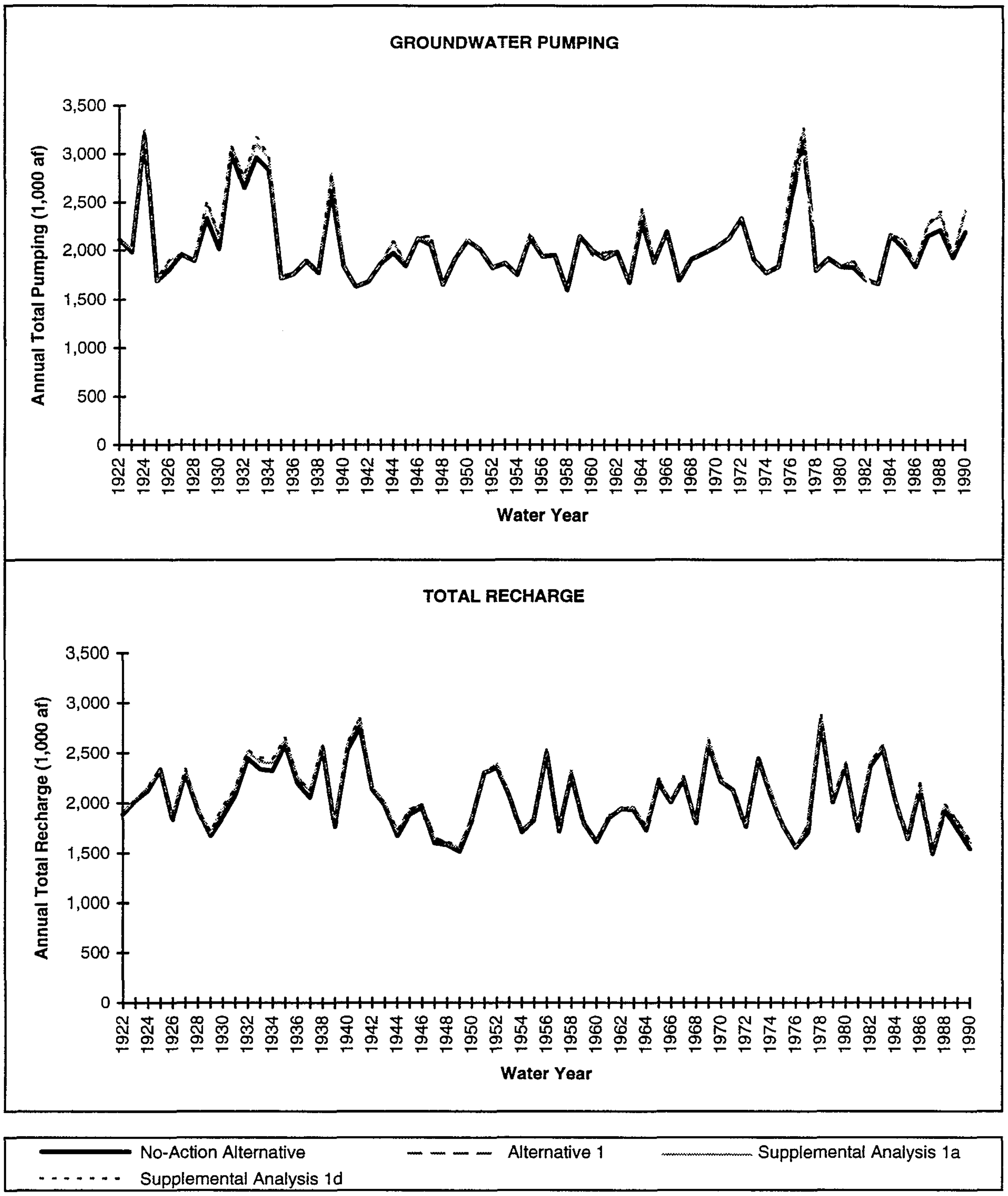
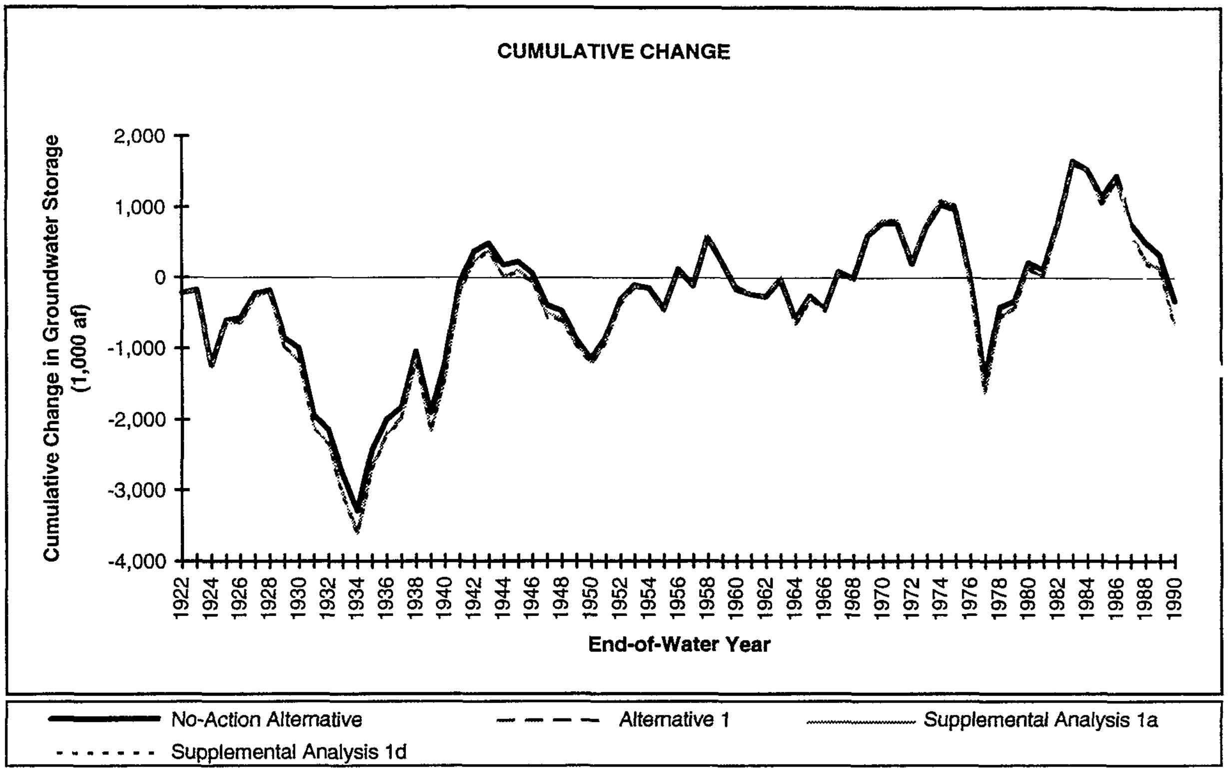


FIGURE III - 17
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SACRAMENTO RIVER REGION (WEST) FOR SUPPLEMENTAL ANALYSES 1a AND 1d



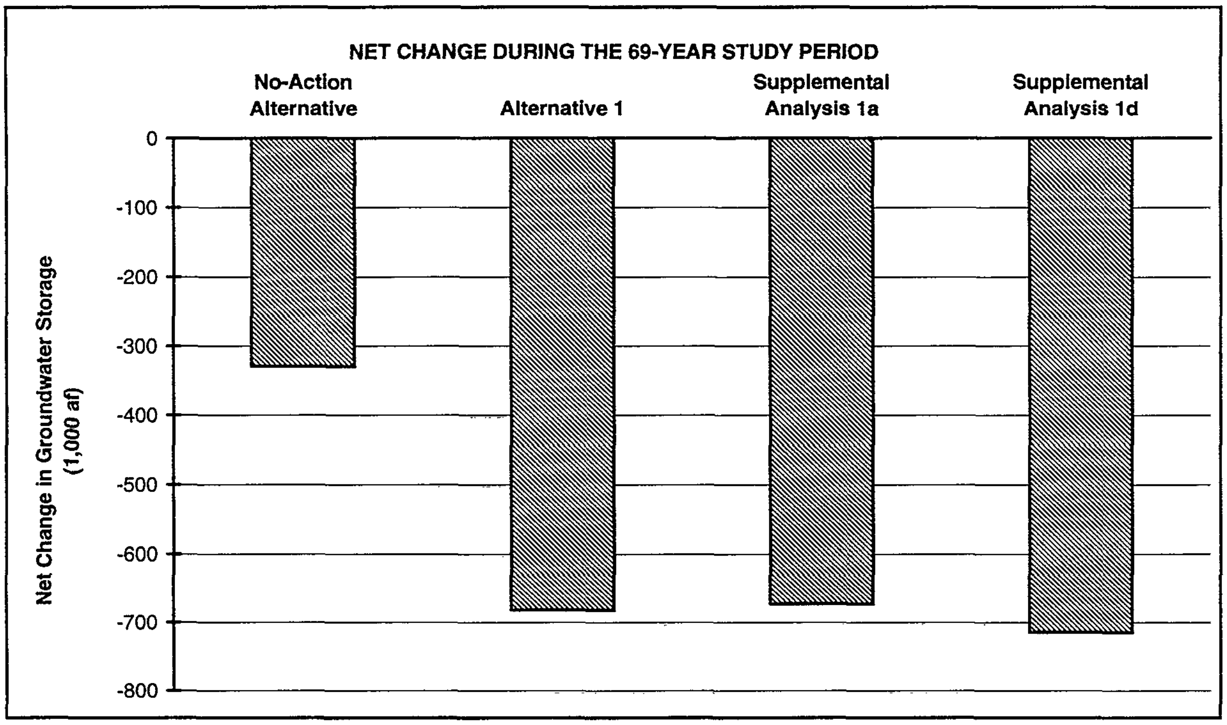


FIGURE III-18
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SACRAMENTO RIVER REGION (WEST) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

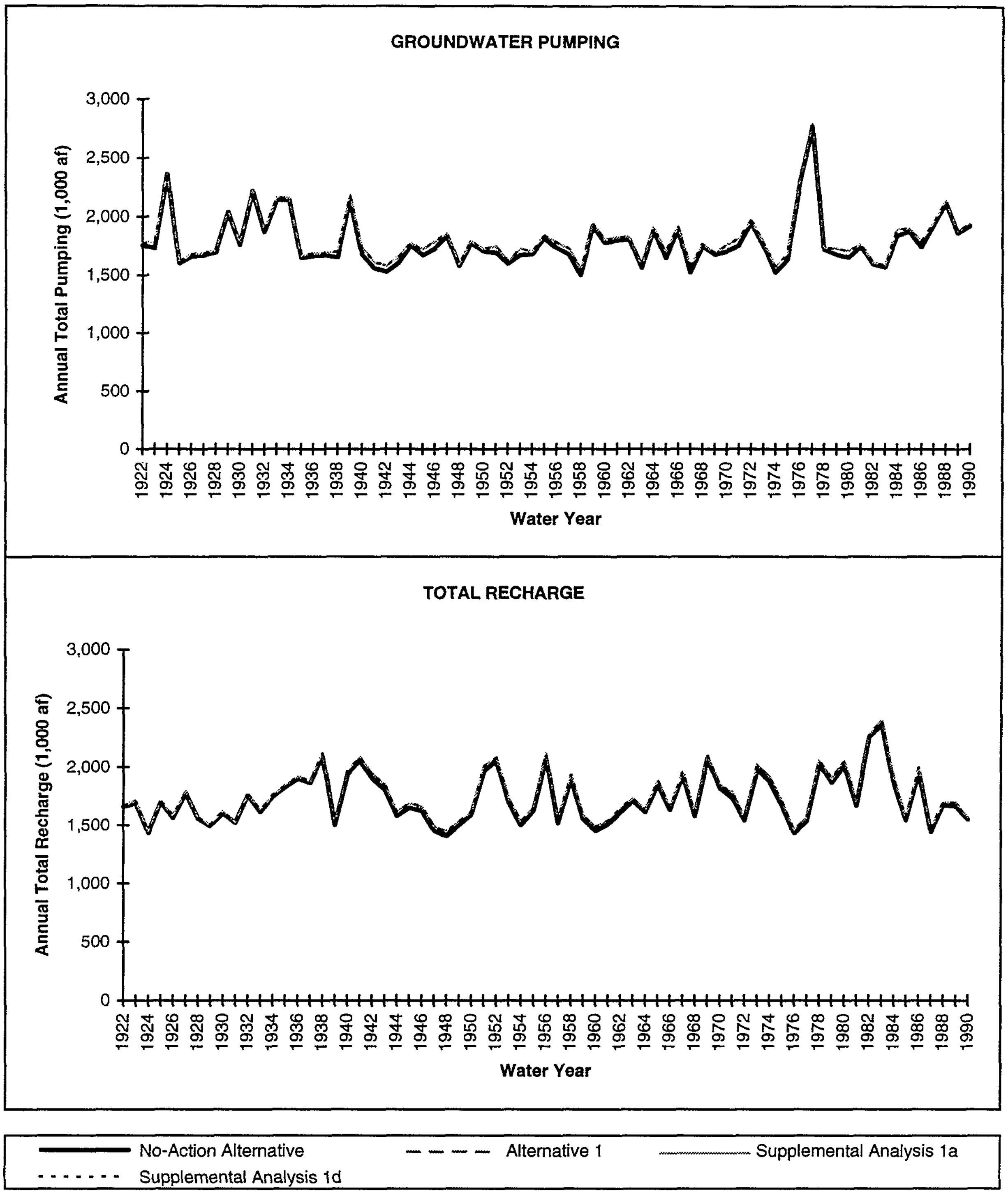
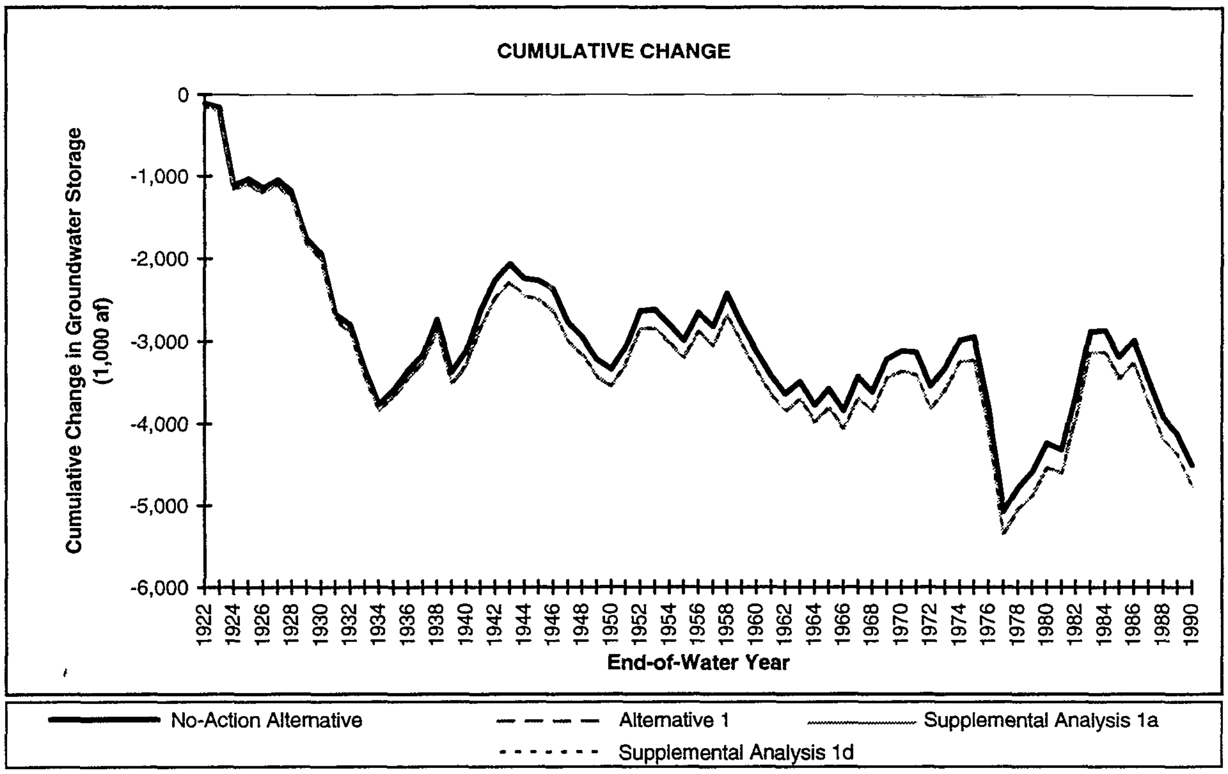


FIGURE III - 19
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SACRAMENTO RIVER REGION (EAST) FOR SUPPLEMENTAL ANALYSES 1a AND 1d



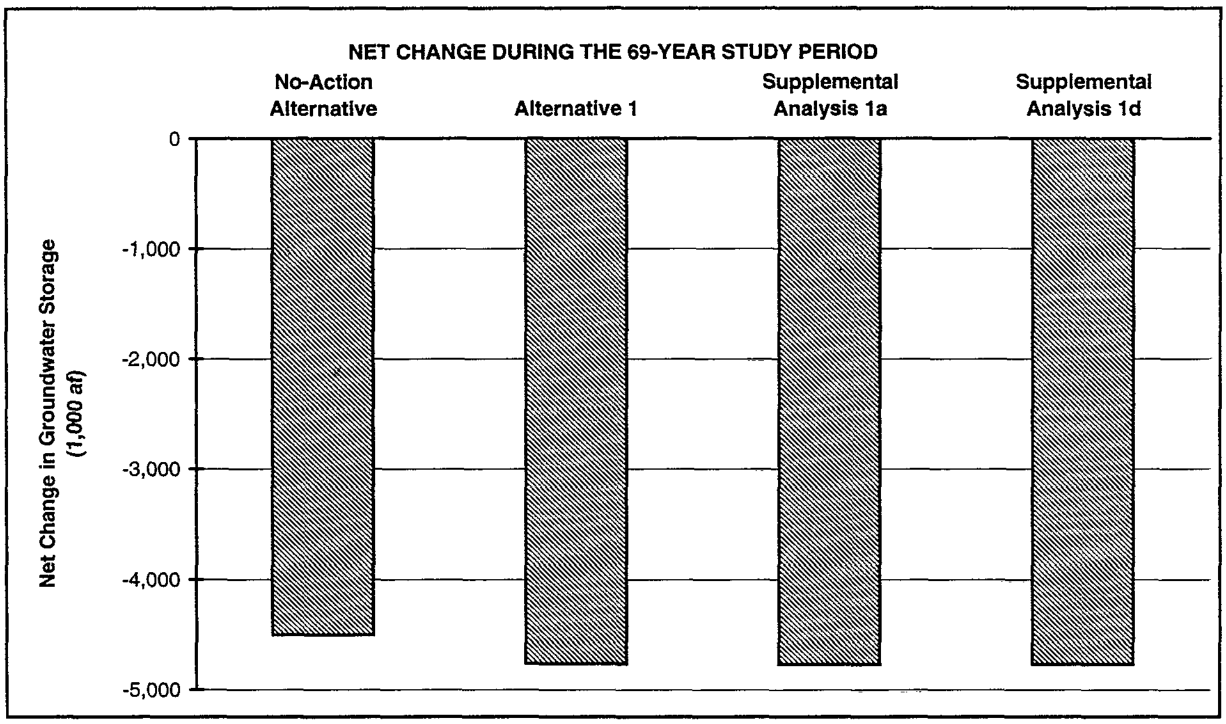


FIGURE III-20
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SACRAMENTO RIVER REGION (EAST) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

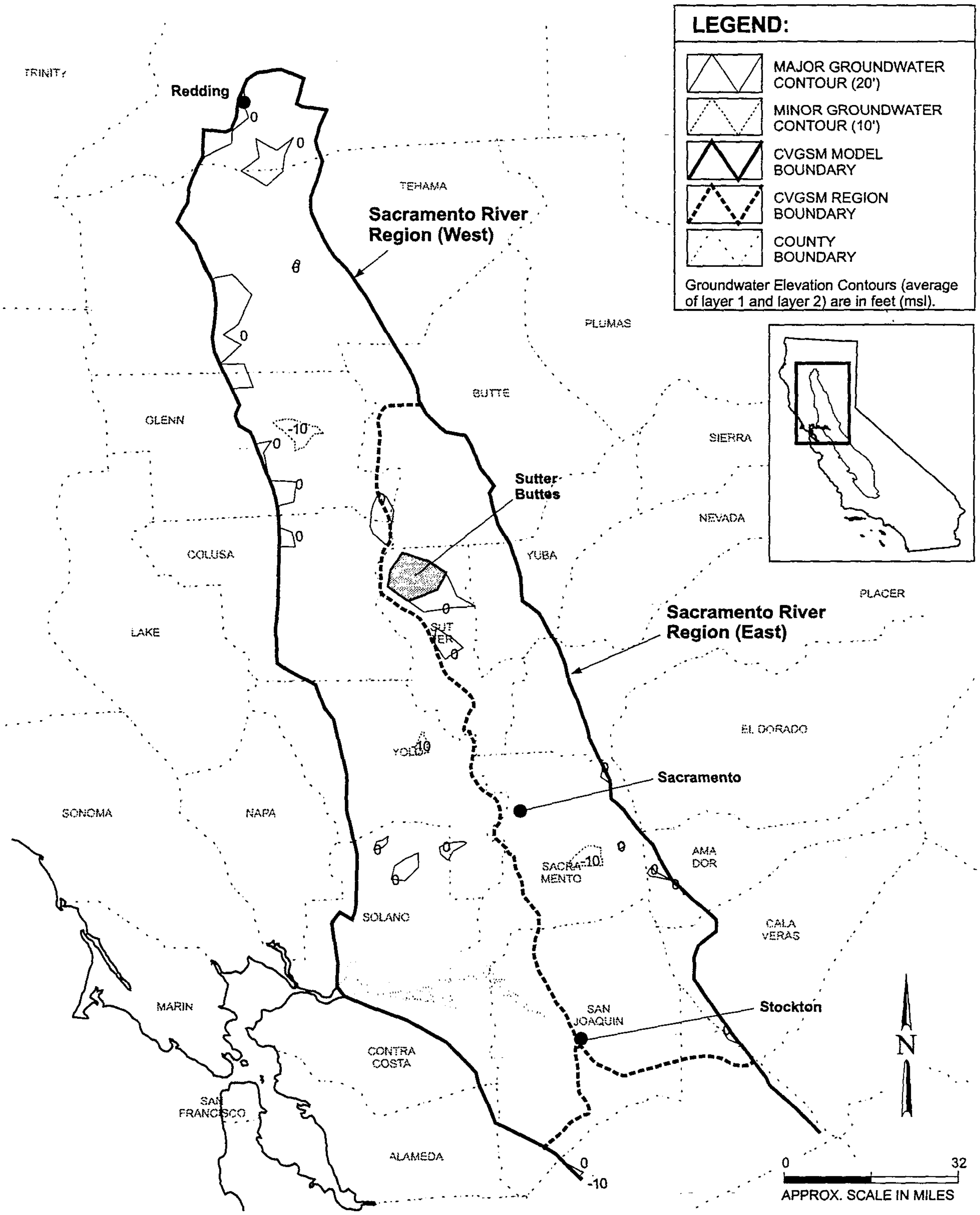


FIGURE III-21a
SACRAMENTO RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR SUPPLEMENTAL ANALYSIS 1a AS COMPARED TO THE NO-ACTION ALTERNATIVE

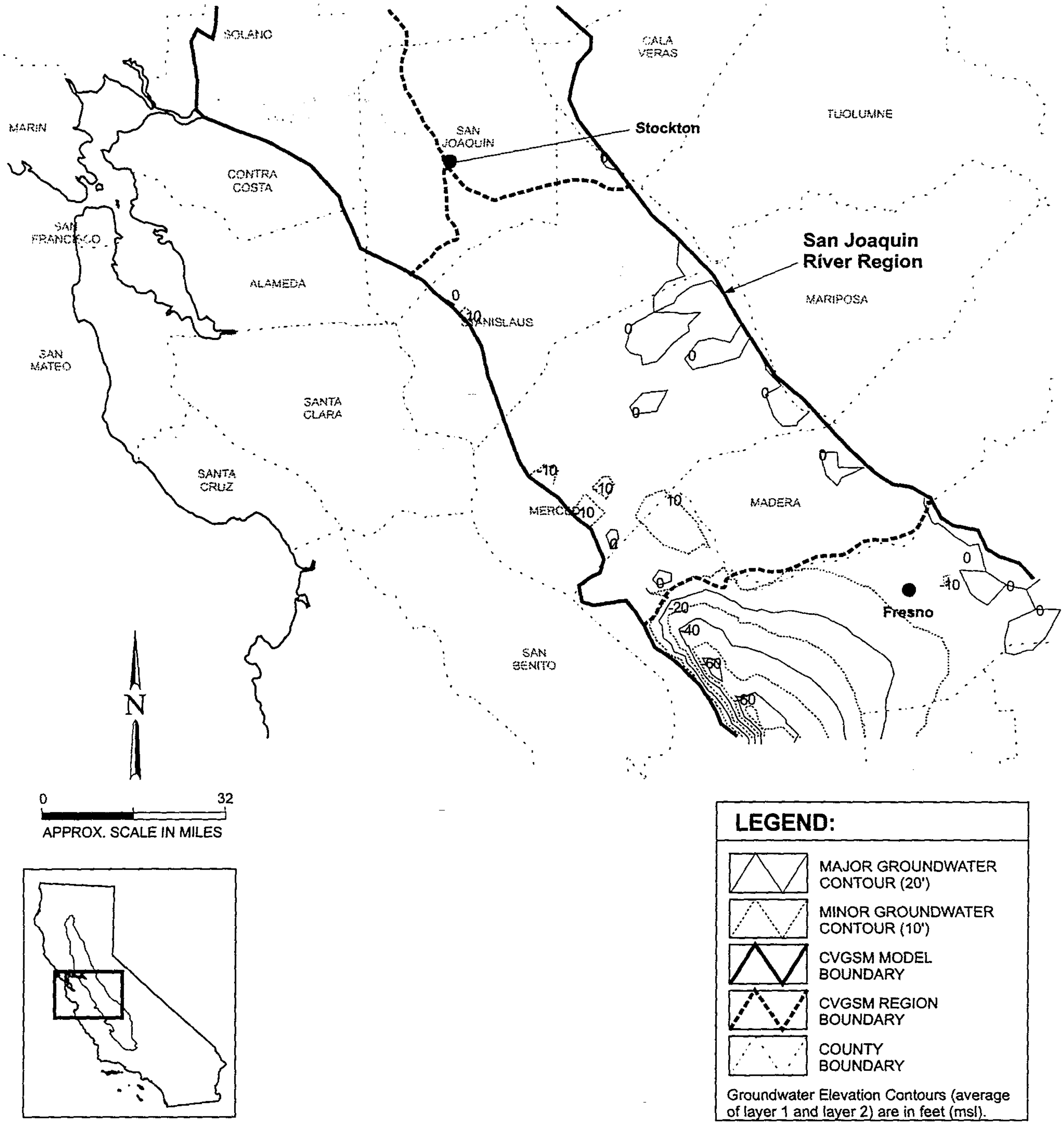


FIGURE III-21b
SAN JOAQUIN RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR SUPPLEMENTAL ANALYSIS 1a AS COMPARED TO THE NO-ACTION ALTERNATIVE

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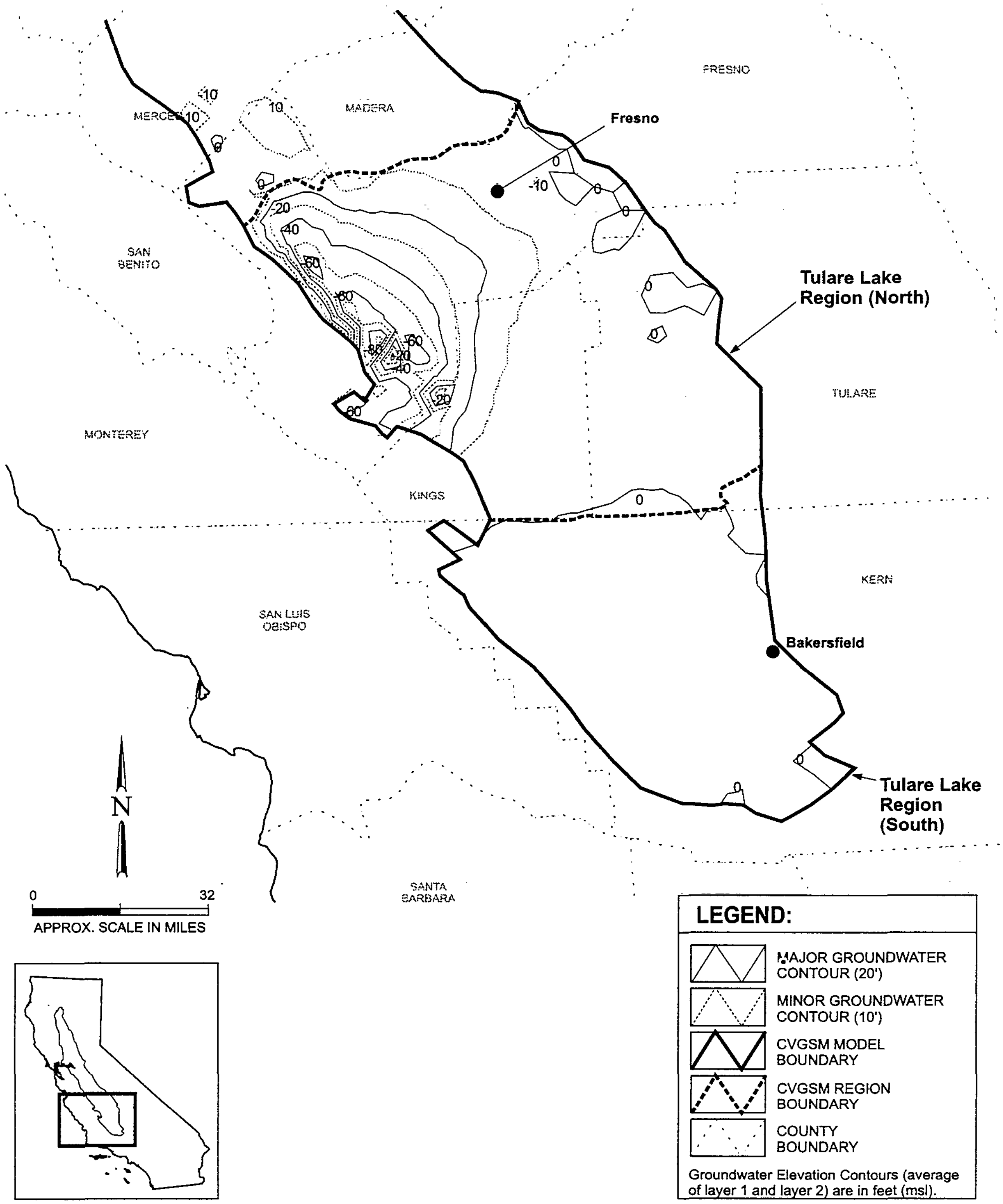


FIGURE III-21c
TULARE LAKE REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR SUPPLEMENTAL ANALYSIS 1a AS COMPARED TO THE NO-ACTION ALTERNATIVE

TABLE III-8

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE SAN JOAQUIN RIVER REGION (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compared to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	1,077	1,086	1,084	1,092	9	7	14
Gain from Streams	313	336	351	346	22	38	33
Recharge (3)	434	447	450	448	13	16	14
Boundary Inflows (4)	24	14	15	18	-10	-9	-6
Total Recharge	**1,849**	**1,883**	**1,900**	**1,904**	**34**	**51**	**56**
Discharge							
Groundwater Pumping	1,875	1,915	1,936	1,937	39	60	62
Total Discharge	**1,875**	**1,915**	**1,936**	**1,937**	**39**	**60**	**62**
Change in Groundwater Storage (5)	**-27**	**-32**	**-36**	**-33**	**-5**	**-9**	**-6**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

assumptions employed for Supplemental Analysis 1a. Groundwater pumping in comparison to Alternative 1 increased by 21,000 acre-feet per year, and by 61,000 acre-feet per year in comparison to the No-Action Alternative. The variation in groundwater pumping and recharge is very similar to Alternative 1 (Figure III-22). The cumulative change in groundwater storage is presented in Figure III-23. The net change in groundwater storage is -2,486,000 acre-feet, which is 287,000 acre-feet of additional groundwater depletion than Alternative 1, and 627,000 acre-feet more than the No-Action Alternative. The additional decline in storage is a result of decreased CVP supplies to the west side of the San Joaquin River Region.

Groundwater Levels

Differences in groundwater levels under Supplemental Analysis 1a from the No-Action Alternative for the end of the 69-year simulation period are shown in Figure III-21b for the San Joaquin River Region (in feet above mean sea level). From a regional perspective, groundwater levels in the north half of the region are the same as Alternative 1. In southwestern corner (the DMC service area) groundwater levels are slightly lower than in Alternative 1. This is expected since CVP deliveries were subject to more frequent deficiencies under the assumptions employed for the Supplemental Analysis 1a analysis.

Land Subsidence

For Supplemental Analysis 1a the range of differences in simulated land subsidence is provided in Figure III-24. Estimated changes in land subsidence relative to the No-Action Alternative are similar to land subsidence summarized for Alternative 1. For Supplemental Analysis 1a land subsidence expanded to the east as a result of additional groundwater level declines in the DMC and San Luis service areas.

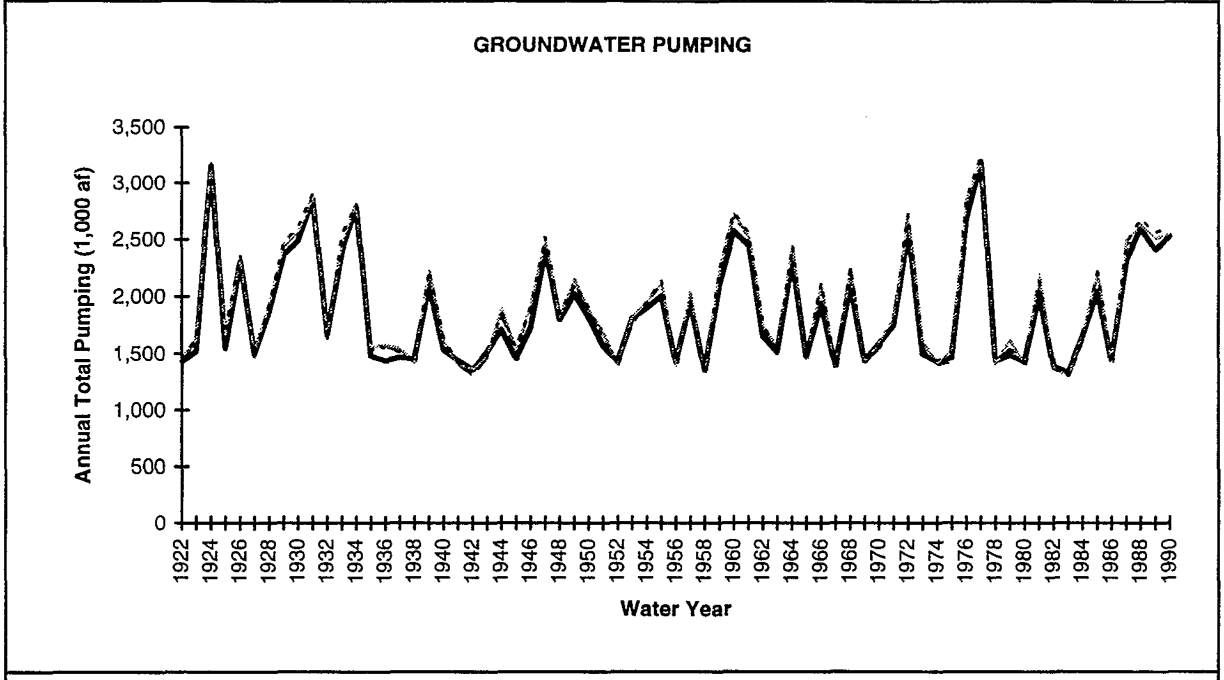
TULARE LAKE REGION

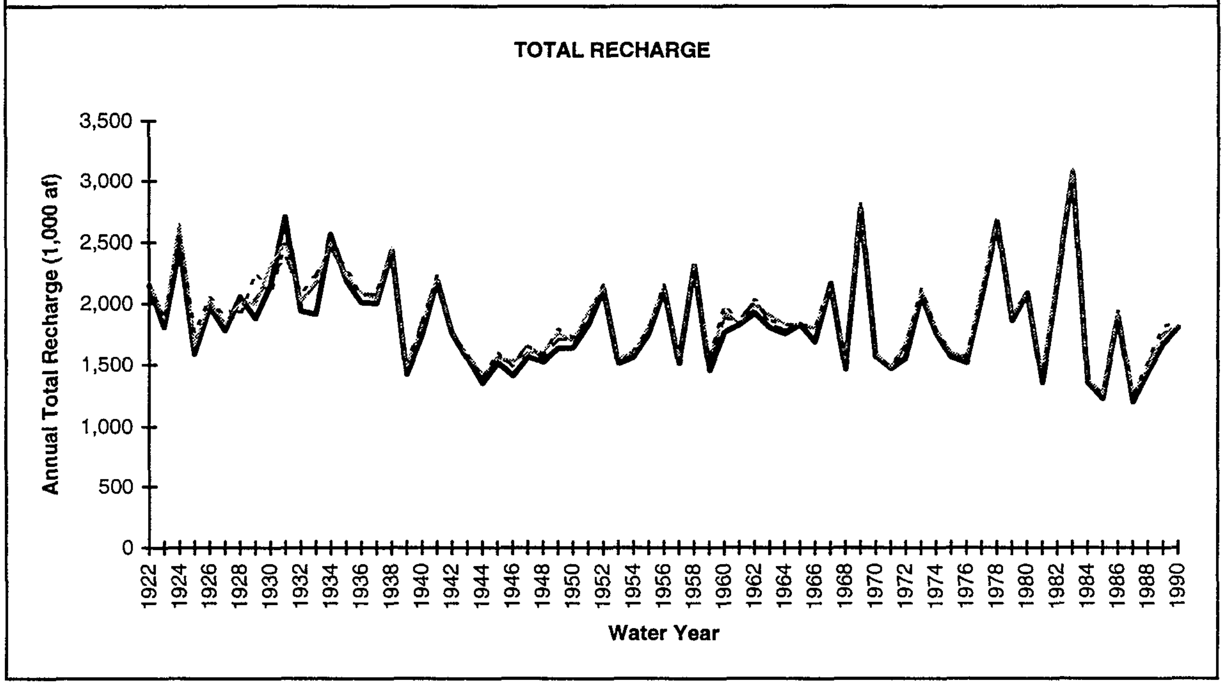
Groundwater Storage and Production

Average annual groundwater conditions for the Tulare Lake Region (North and South) under Supplemental Analysis 1a are presented in Tables III-9 and III-10. The variation in groundwater pumping, recharge, and groundwater storage for the north area are shown in Figures III-25 and III-26. An increase in groundwater pumping of approximately 48,000 acre-feet per year above Alternative 1, and 134,000 acre-feet per year above the No-Action Alternative, would occur as a result of reductions in CVP deliveries. The net change in groundwater storage for the north area is -22,177,000 acre-feet, which amounts to 1,771,000 acre-feet morel groundwater depletion than occurred in Alternative 1, and 5,387,000 acre-feet more than the No-Action Alternative. Groundwater conditions in the southern portion of this region are very similar to Alternative 1 (see Figures III-27 and III-28).

Groundwater Levels

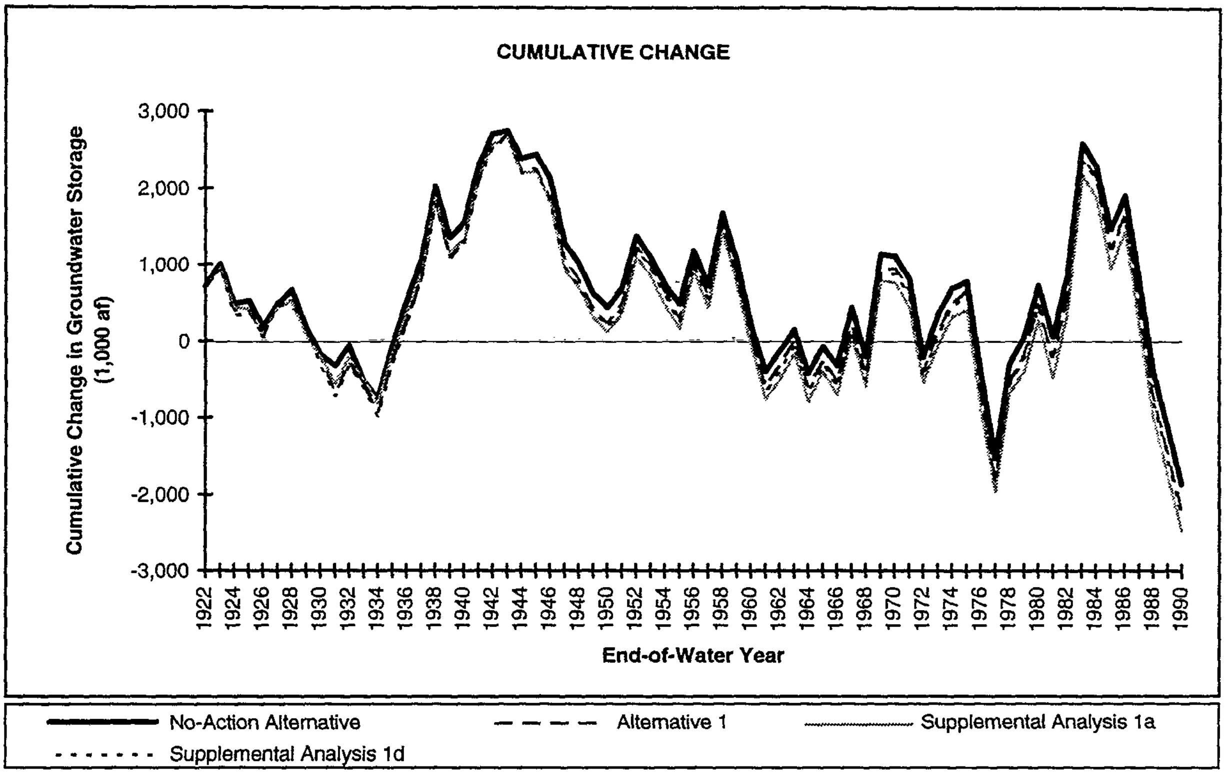
Differences in groundwater levels for the Tulare Lake Region under Supplemental Analysis 1a for the end of the 69-year simulation period, as compared to the No-Action Alternative, are shown in Figure III-21c. From a regional perspective, groundwater levels in the north half indicate a





No-Action Alternative — Alternative 1 — Supplemental Analysis 1a — Supplemental Analysis 1d

FIGURE III - 22
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE SAN JOAQUIN RIVER REGION FOR SUPPLEMENTAL ANALYSES 1a AND 1d



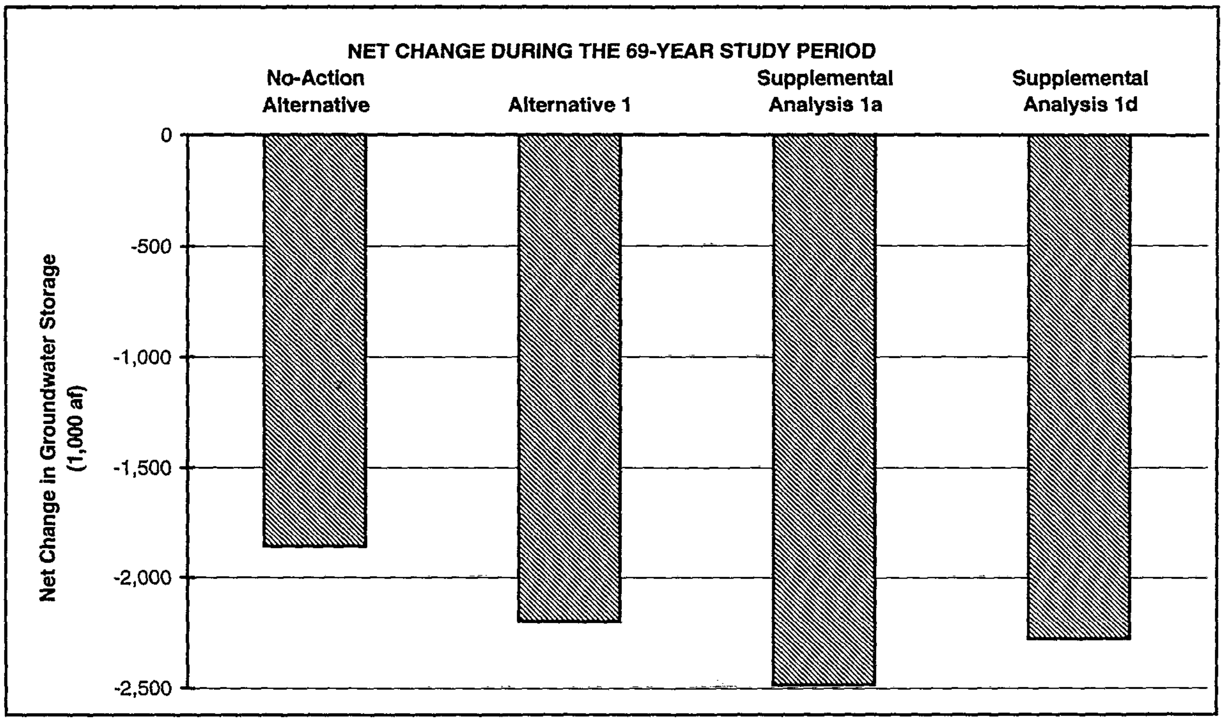
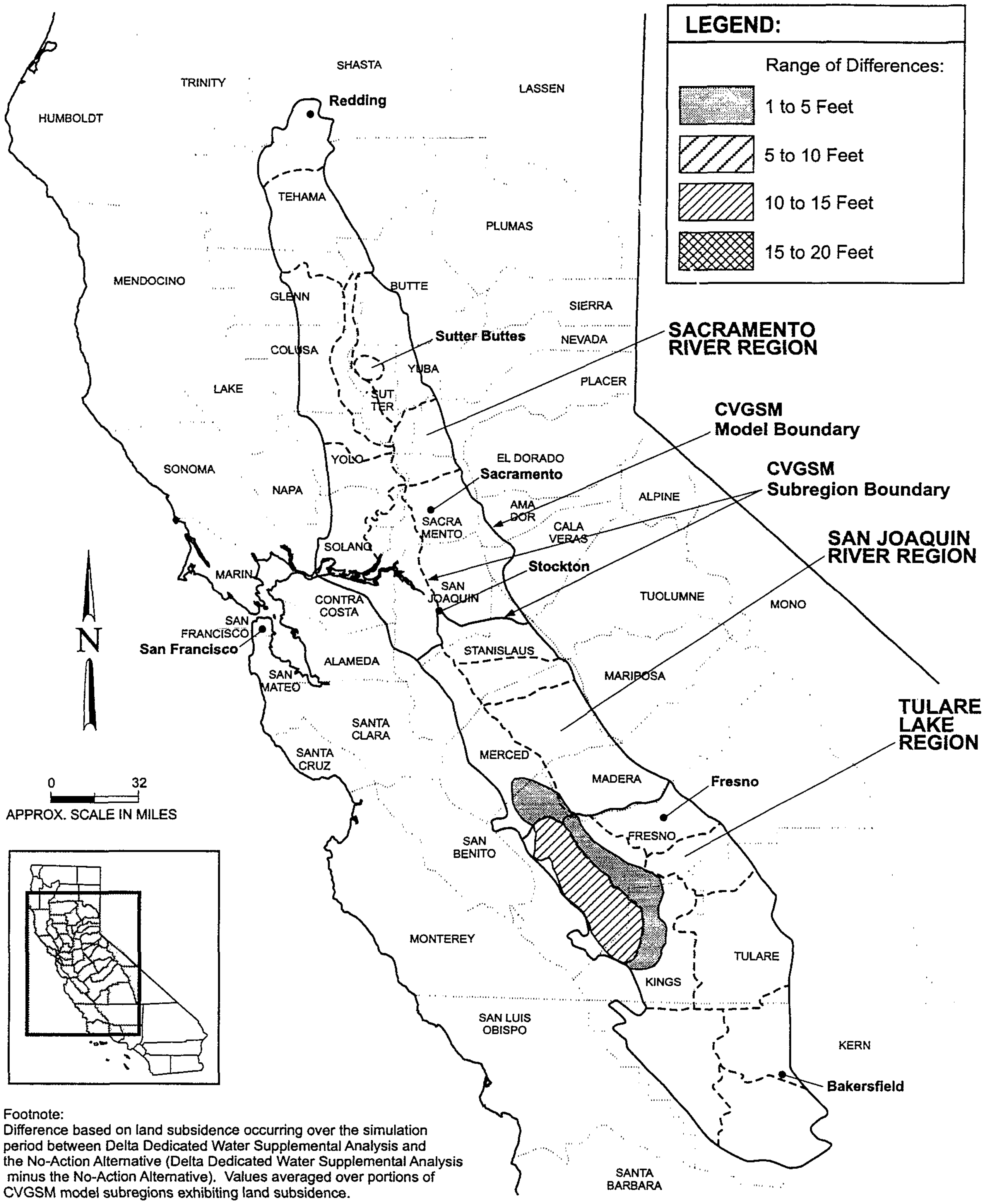


FIGURE III-23
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE SAN JOAQUIN RIVER REGION FOR SUPPLEMENTAL ANALYSES 1a AND 1d



Footnote:
Difference based on land subsidence occurring over the simulation period between Delta Dedicated Water Supplemental Analysis and the No-Action Alternative (Delta Dedicated Water Supplemental Analysis minus the No-Action Alternative). Values averaged over portions of CVGSM model subregions exhibiting land subsidence.

FIGURE III-24

REGIONAL DIFFERENCES IN SIMULATED LAND SUBSIDENCE IN ALTERNATIVE 1a FROM NO-ACTION ALTERNATIVE

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TABLE III-9

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE TULARE LAKE REGION (NORTH) (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compared to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	1,696	1,655	1,645	1,655	-41	-52	-41
Gain from Streams	500	507	514	507	7	14	8
Recharge (3)	396	417	423	417	21	27	21
Boundary Inflows (4)	1,208	1,254	1,274	1,256	47	66	49
Total Recharge	**3,799**	**3,833**	**3,855**	**3,836**	**34**	**56**	**37**
Discharge							
Groundwater Pumping	4,043	4,129	4,177	4,133	86	134	90
Total Discharge	**4,043**	**4,129**	**4,177**	**4,133**	**86**	**134**	**90**
Change in Groundwater Storage (5)	**-243**	**-296**	**-321**	**-296**	**-52**	**-78**	**-53**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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TABLE III-10

AVERAGE ANNUAL GROUNDWATER BUDGET FOR THE TULARE LAKE REGION (SOUTH) (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compared to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	958	964	963	964	6	5	6
Gain from Streams	225	216	222	216	-8	-3	-8
Recharge (3)	124	120	122	120	-4	-3	-4
Boundary Inflows (4)	222	213	216	213	-9	-6	-9
Total Recharge	**1,529**	**1,513**	**1,522**	**1,513**	**-15**	**-7**	**-15**
Discharge							
Groundwater Pumping	1,411	1,380	1,393	1,380	-31	-18	-31
Total Discharge	**1,411**	**1,380**	**1,393**	**1,380**	**-31**	**-18**	**-31**
Change in Groundwater Storage (5)	**118**	**133**	**129**	**133**	**16**	**11**	**15**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

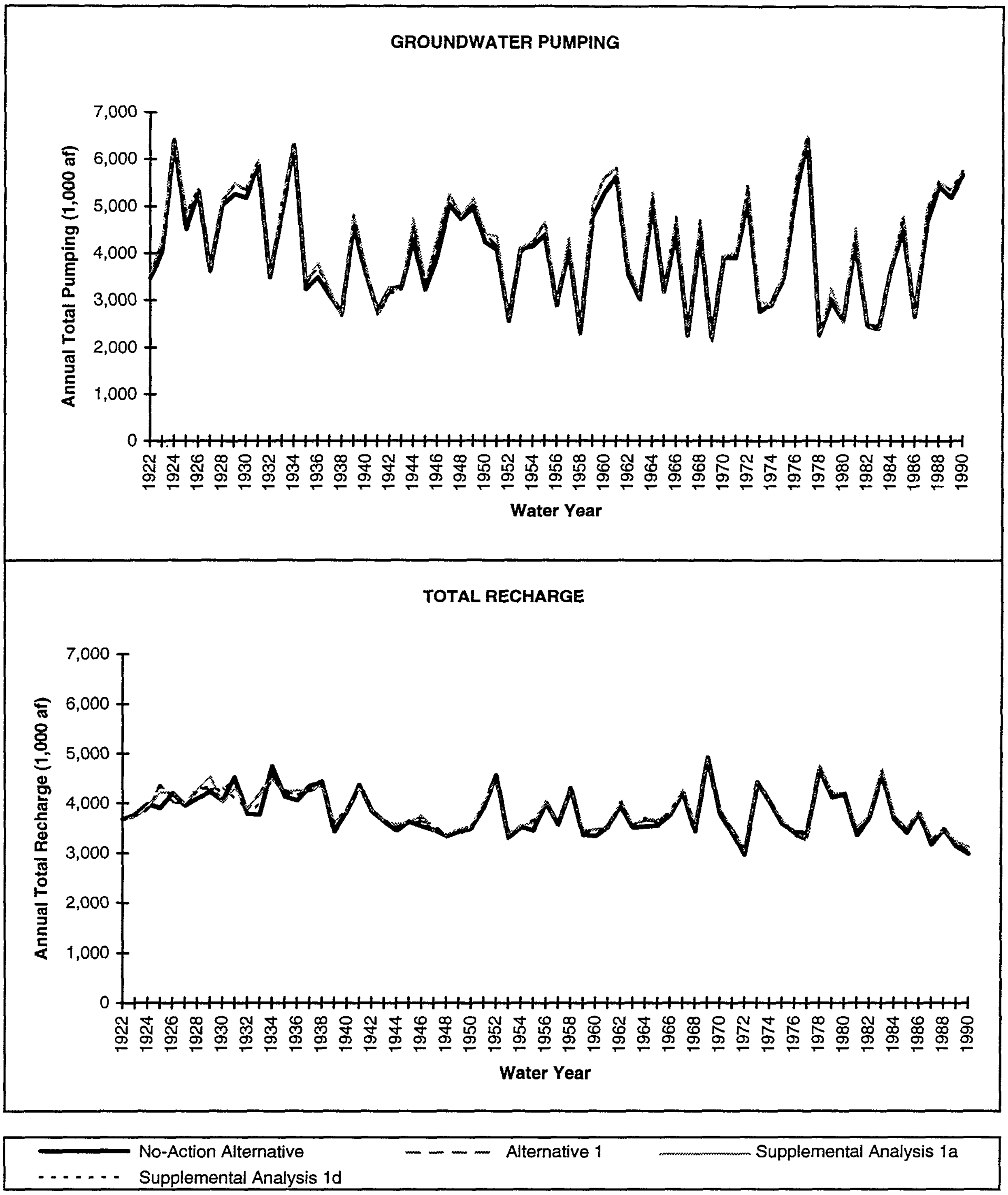
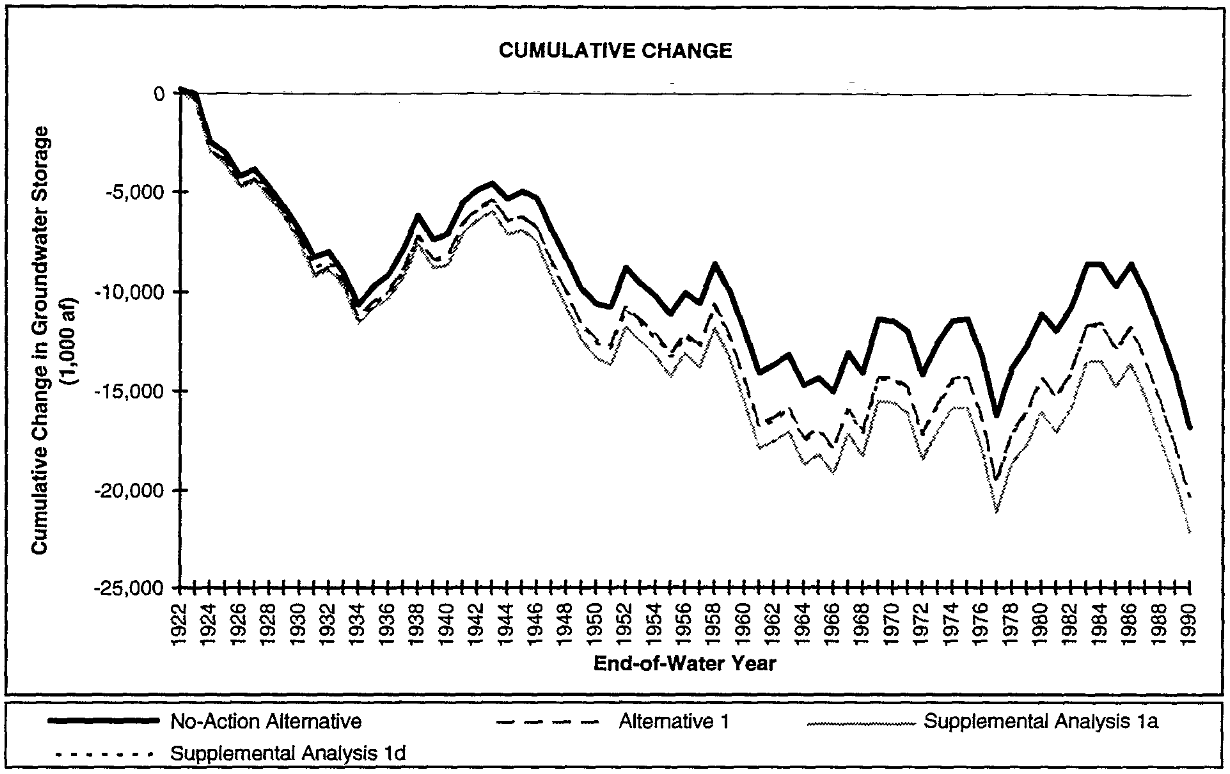


FIGURE III - 25
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE TULARE LAKE REGION (NORTH) FOR SUPPLEMENTAL ANALYSES 1a AND 1d



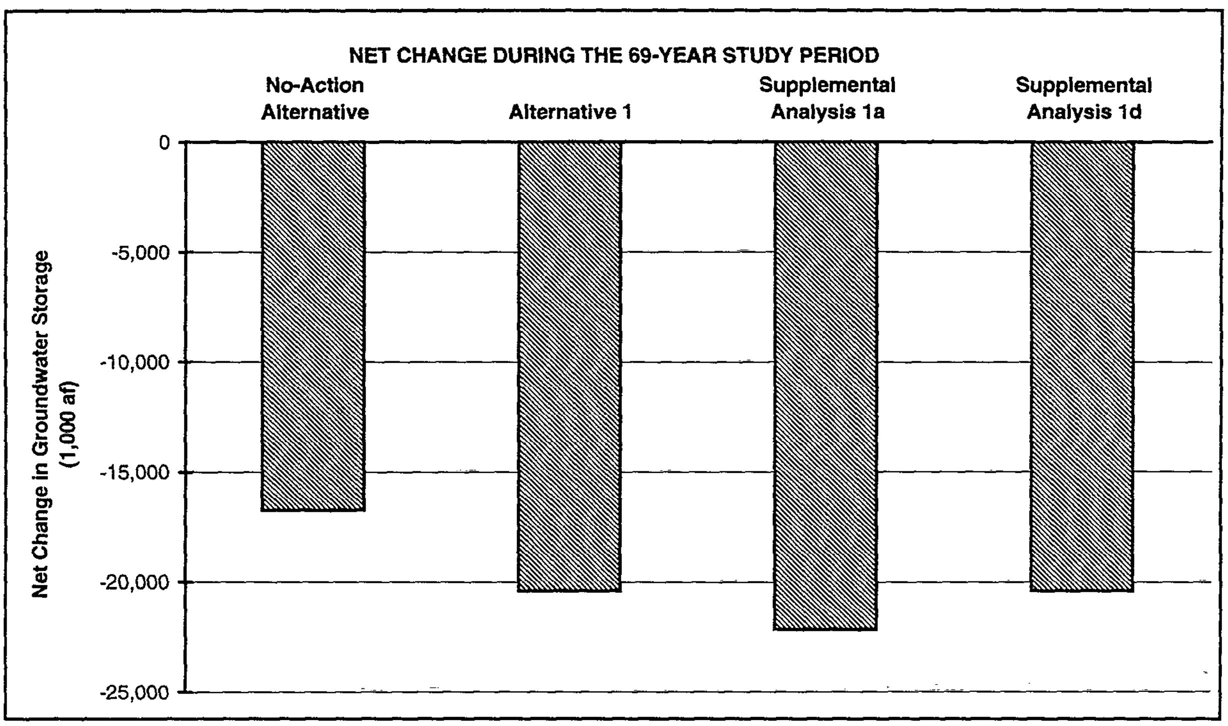


FIGURE III-26
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE TULARE LAKE REGION (NORTH) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

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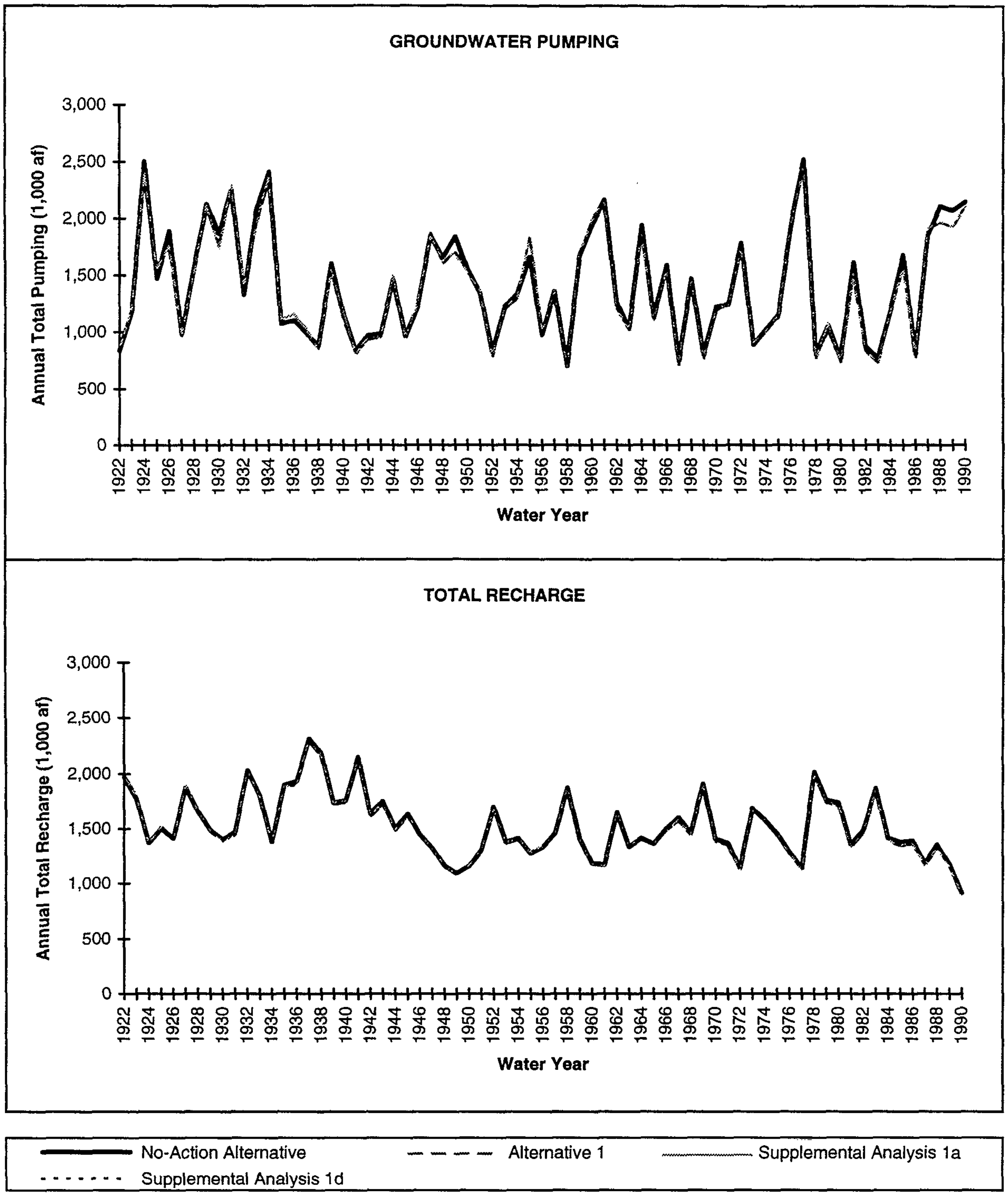
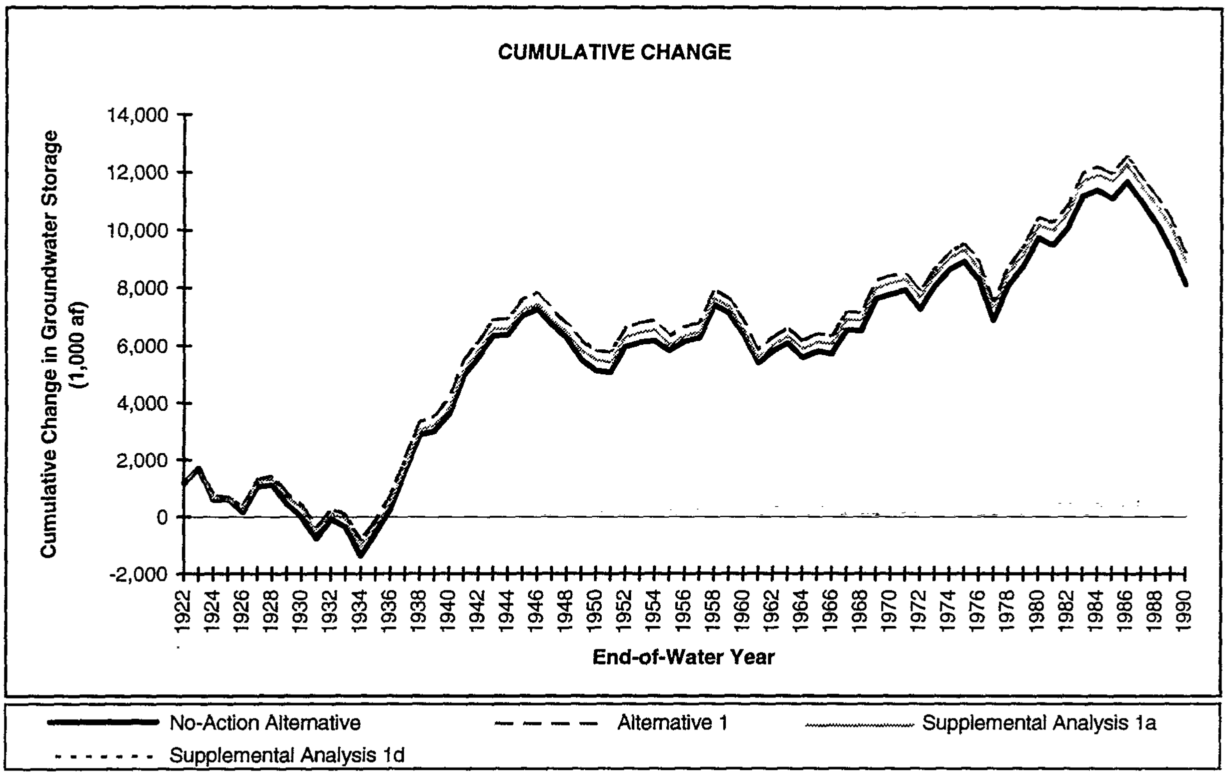


FIGURE III - 27
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR THE TULARE LAKE REGION (SOUTH) FOR SUPPLEMENTAL ANALYSES 1a AND 1d



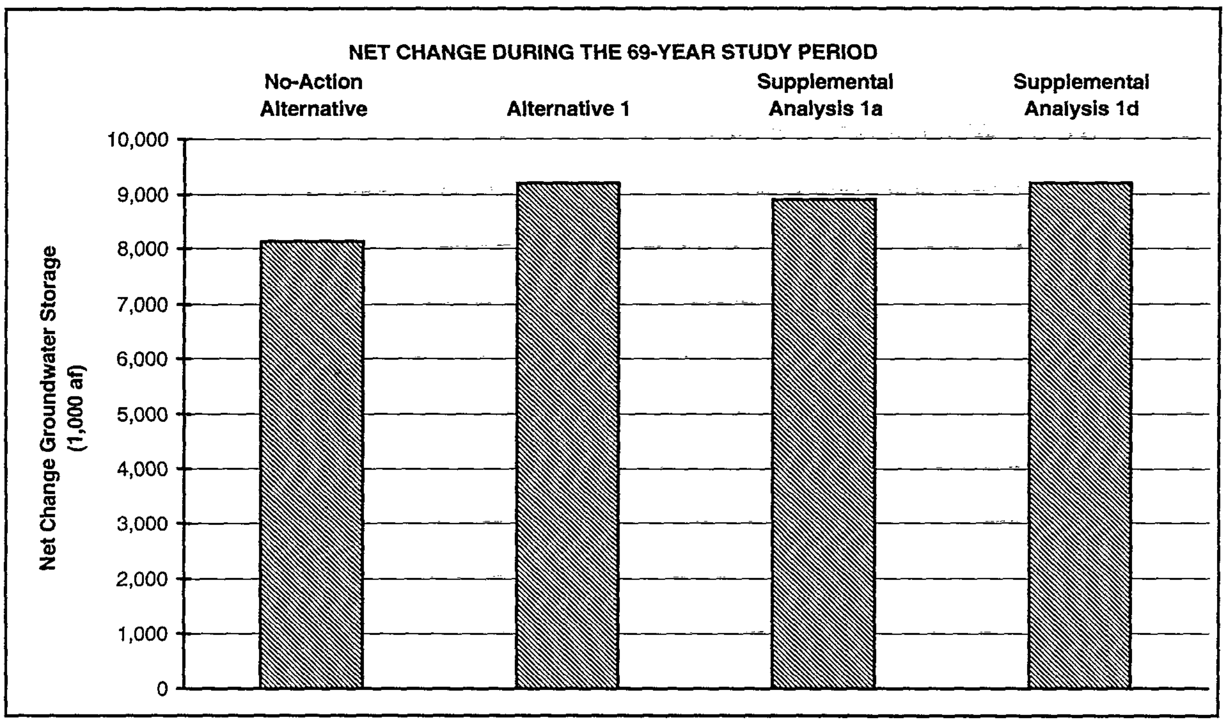


FIGURE III-28
SIMULATED GROUNDWATER STORAGE CONDITIONS FOR THE TULARE LAKE REGION (SOUTH) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

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larger area of lower groundwater levels for Supplemental Analysis 1a than observed previously in Alternative 1. Groundwater levels in the southern portion of the area are very similar to Alternative 1.

Land Subsidence

See the earlier discussion under the San Joaquin River Region.

SAN FRANCISCO BAY REGION

Under Supplemental Analysis 1a, CVP deliveries to Santa Clara and San Benito counties would decrease on average 22,000 acre-feet per year relative to the No-Action Alternative. Local regulation of groundwater extraction by means of pump taxes, such as those levied by the SCVWD, would discourage replacement of this CVP water with groundwater. For the purposes of this programmatic level of analysis it is assumed that any increase in groundwater pumping to offset these reduced CVP deliveries would be minimal. A small impact to groundwater conditions could occur in the vicinity of spreading basins as a result of lost deep percolation associated with the reduced CVP deliveries.

Under Supplemental Analysis 1a, CVP deliveries to Alameda and Contra Costa counties would be similar to the No-Action Alternative. Under these conditions no net impact to groundwater storage, levels, and quality would occur, and no additional land subsidence would occur in these areas.

SUPPLEMENTAL ANALYSIS 1d

Under Alternative 1 CVP Level 2 deliveries to wildlife refuges were subject to shortages up to 25 percent, when irrigation water shortages were at least that large. The Supplemental Analysis 1d assesses the incremental impacts if wildlife refuges receive no shortages in Level 2 delivery. Other assumptions underlying this analysis are the same as those for Alternative 1.

SACRAMENTO RIVER REGION

Average annual groundwater conditions for the Sacramento River Region under Supplemental Analysis 1d, as compared to the No-Action Alternative, are summarized in Tables III-6 and III-7. Annual groundwater conditions as compared to the No-Action Alternative are shown in Figures III-17, III-18, III-19, and III-20. In general, regional groundwater conditions for Supplemental Analysis 1d in the Sacramento River Region are similar to Alternative 1. The west side of the Sacramento River Region would have a small increase in groundwater pumping as a result of small decreases in average annual CVP surface water deliveries in this area. This is countered by an equivalent increase in recharge resulting from percolation of the additional refuge deliveries.

SAN JOAQUIN RIVER REGION

Groundwater conditions for Supplemental Analysis 1d as compared to the No-Action Alternative are reported in Table III-8 and Figures III-22 and III-23. Changes in groundwater conditions in the San Joaquin River Region are similar to Alternative 1.

TULARE LAKE REGION

Average annual groundwater conditions for the Tulare Lake Region under Supplemental Analysis 1d, as compared to the No-Action Alternative, are summarized in Tables III-9 and III-10. Annual groundwater conditions as compared to the No-Action Alternative are shown in Figures III-25, III-26, III-27, and III-28. In general, regional groundwater conditions for Supplemental Analysis 1d in the Tulare Lake Region are similar to Alternative 1.

SAN FRANCISCO BAY REGION

Changes in CVP deliveries to the San Francisco Bay Region would be the same as in Alternative 1. Impacts to groundwater resources as compared to the No-Action Alternative would be similar to those described for Alternative 1.

ALTERNATIVE 2

Alternative 2 includes the same assumptions for the groundwater analysis as Alternative 1, with the addition of acquired water from willing sellers for Level 4 refuge supply and instream flow needs on east side San Joaquin River tributaries (Stanislaus, Tuolumne, and Merced rivers). These acquisitions are limited by the amount of funds assumed to be available in the CVPIA Restoration Fund. In order to prevent groundwater replacement of acquired surface water, the analysis attempted to hold long-term average annual groundwater pumping to no more than the Alternative 1 level in subregions where water is acquired. However, economic incentive, triggered by other regions retiring lands due to water acquisitions, was responsible for increases in certain crop types in some areas resulting in increased groundwater pumping in these areas (see Attachment A). The acquired water actions result in changes in crop mix and crop acreage, and irrigation technology which are reflected as changes in water and land use practices in the groundwater analysis.

SACRAMENTO RIVER REGION

The differences between Alternative 2 and the No-Action Alternative in groundwater levels at the end of the 69-year simulation period are shown in Figure III-29a. Long-term regional groundwater conditions in the Sacramento River Region would be similar to Alternative 1, with the exception of small changes in groundwater levels in response to additional deep percolation from increased refuge supplies.

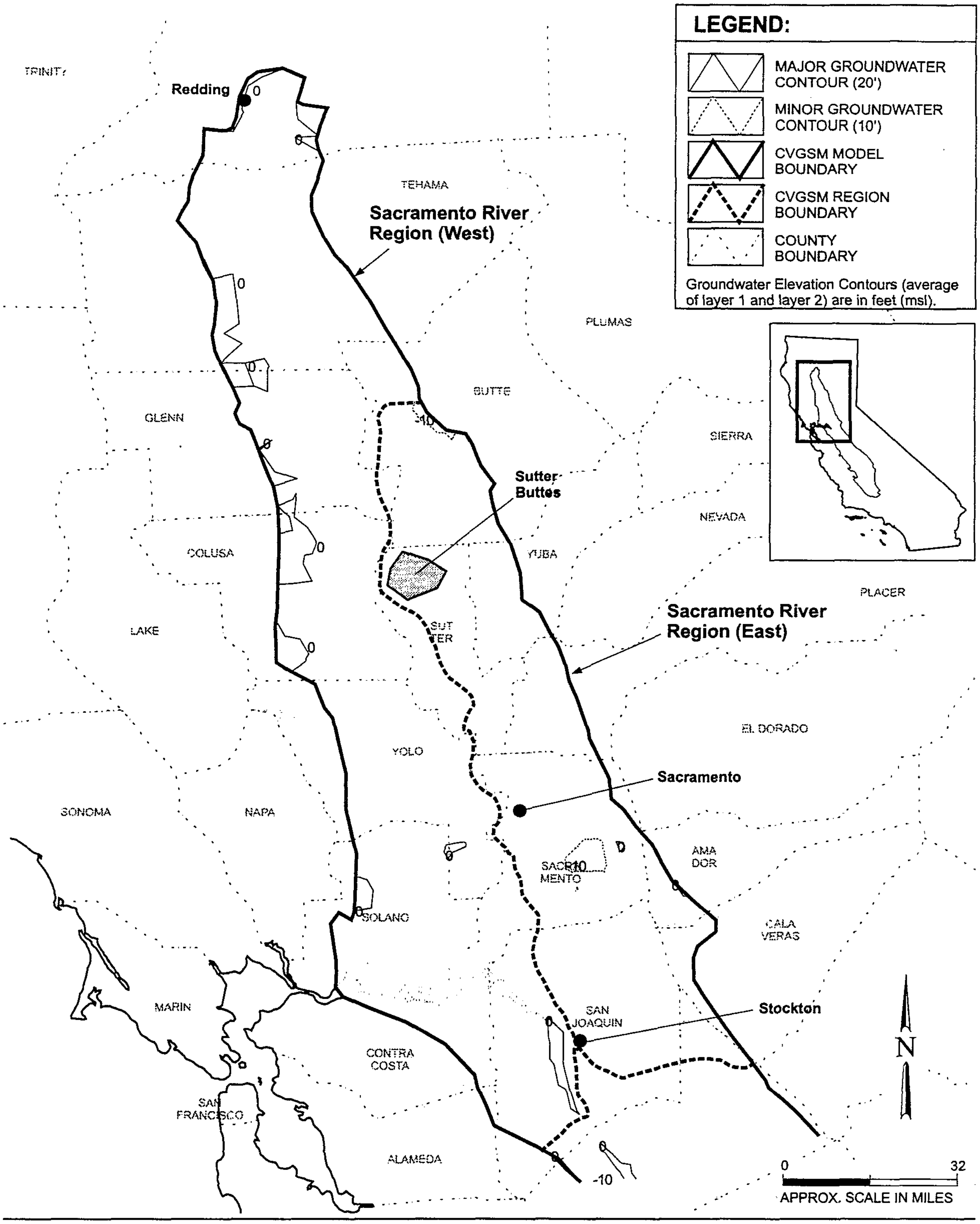


FIGURE III-29a
SACRAMENTO RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 2 AS COMPARED TO THE NO-ACTION ALTERNATIVE

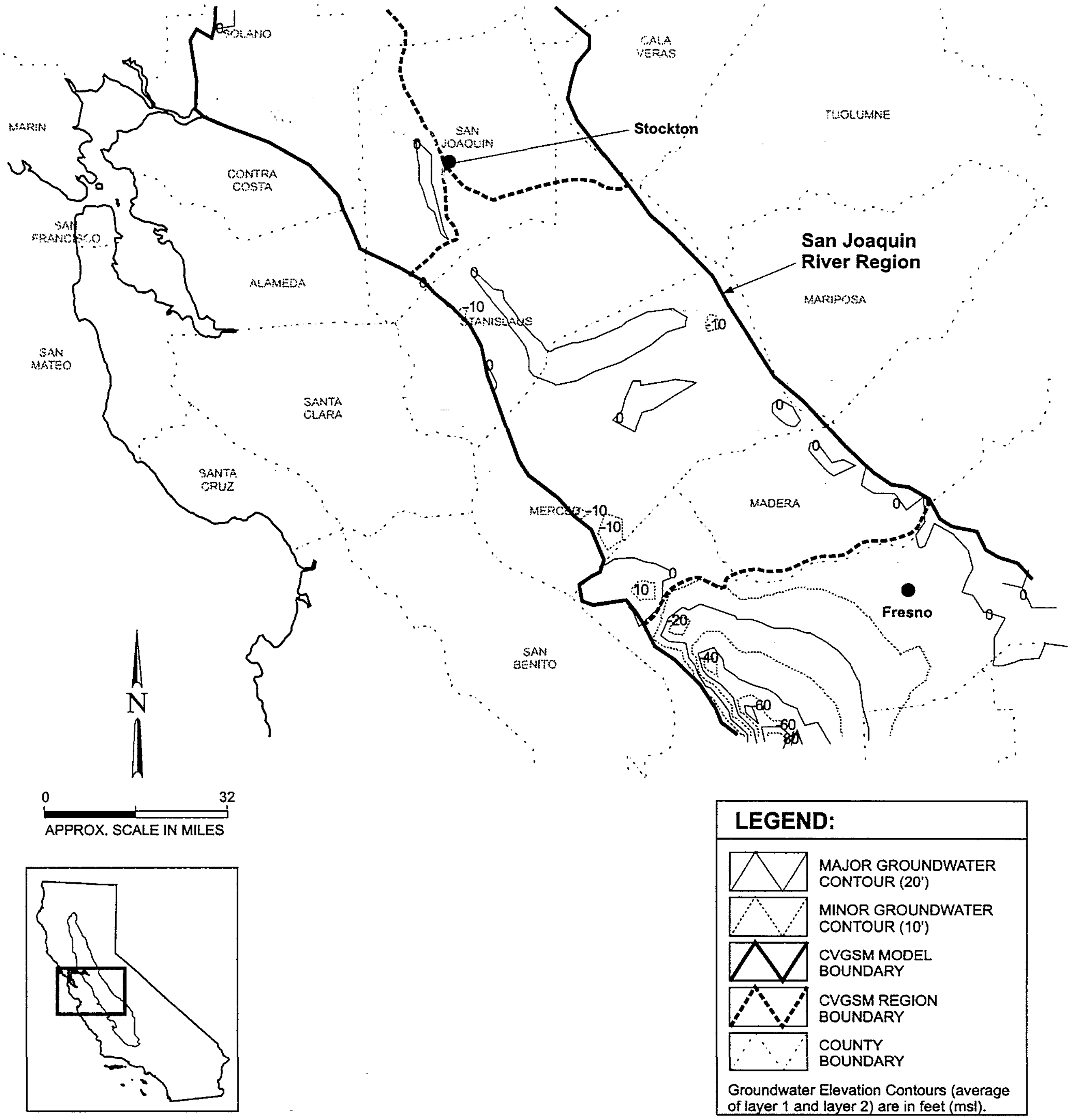


FIGURE III-29b
SAN JOAQUIN RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 2 AS COMPARED TO THE NO-ACTION ALTERNATIVE

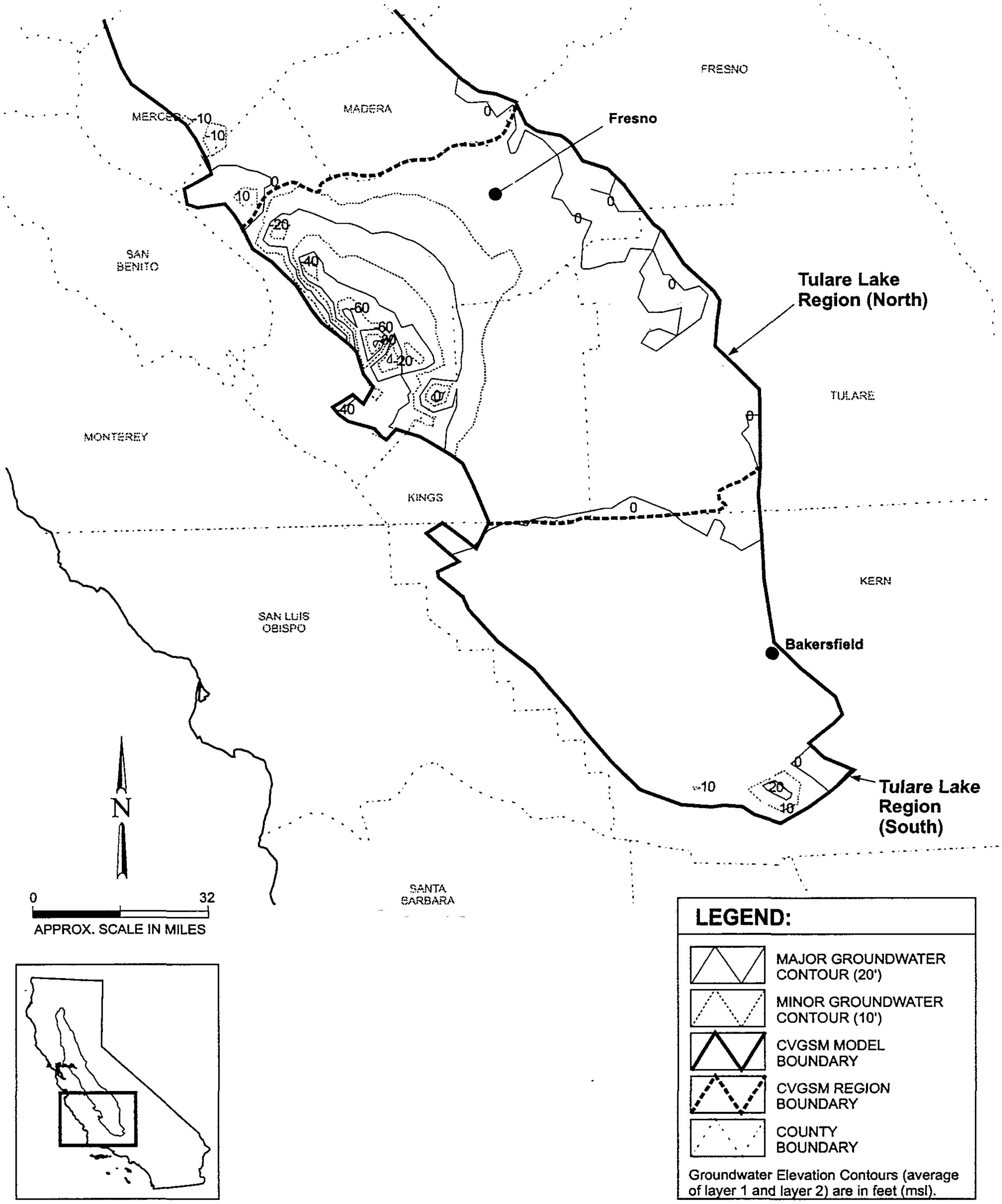


FIGURE III-29c
TULARE LAKE REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 2 AS COMPARED TO THE NO-ACTION ALTERNATIVE

Groundwater Storage and Production

Sacramento River Region (West). Average annual groundwater conditions for the Sacramento River Region (West) under Alternative 2 are presented in Table III-1. Annual variations for groundwater pumping, recharge, and storage are presented in Figures III-2 and III-3. As indicated by these figures, Alternative 2 groundwater conditions are similar to Alternative 1. The deep percolation component for Alternative 2 relative to the No-Action Alternative is slightly higher than Alternative 1 relative to the No-Action Alternative. This is because of the acquisition of surface water to meet Level 4 refuge water supply deliveries in this area. However, this increase was completely offset by a decrease in stream losses to the groundwater basin. This decrease is caused by regional increases in groundwater levels. The increase in deep percolation combined with the decrease in stream losses resulted in similar total recharge conditions between Alternative 2 and Alternative 1.

Sacramento River Region (East). Average annual groundwater conditions for the Sacramento River Region (East) under Alternative 2 are presented in Table III-2. Annual variations for groundwater pumping, recharge, and storage are presented in Figures III-4 and III-5. As indicated by these figures, Alternative 2 groundwater conditions are similar to Alternative 1. Average annual groundwater pumping in Alternative 2 would be slightly higher than Alternative 1. This is caused by economic incentive to replace acreage retired in the San Joaquin River Region due to water acquisitions (see Attachment A for additional information).

Groundwater Levels

Differences in groundwater levels under Alternative 2 from the No-Action Alternative for the end of the 69-year simulation period are shown in Figure III-29a for the Sacramento River Region (in feet above mean sea level). From a regional perspective, groundwater levels are the same as the No-Action Alternative. Groundwater levels are lower by approximately 10 feet in the Sacramento County area. Groundwater level declines that existed in isolated locations in Alternative 1 along the west side do not develop in Alternative 2 primarily because of increased refuge supplies in the region. On a regional basis under Alternative 2 the hydraulic connection between streams and underlying groundwater tables is similar to the No-Action Alternative.

Land Subsidence

Under Alternative 2, with groundwater levels declining very little in this area, no additional land subsidence in comparison to the No-Action Alternative would occur.

Groundwater Quality

Under Alternative 2, with groundwater levels declining very little in this area, it is expected that groundwater quality in the Sacramento River Region would not change in comparison to the No-Action Alternative.

Agricultural Subsurface Drainage

Under Alternative 2, with groundwater levels declining very little in this area, it is expected that agricultural subsurface drainage problems in the Sacramento River Region would not change in comparison to the No-Action Alternative.

Seepage and Waterlogging

Sacramento River summer flows and adjacent groundwater levels are the similar to Alternative 1, resulting in similar changes to seepage-induced waterlogging problems. See the Alternative 1 seepage impact assessment.

SAN JOAQUIN RIVER REGION

Differences in groundwater levels between Alternative 2 and the No-Action Alternative for the San Joaquin River Region are shown in Figure III-29b. Regionally, long-term groundwater conditions would be similar to Alternative 1, however, some localized differences occur as a result of acquired water in the east side tributary areas of the San Joaquin River basin.

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under Alternative 2 are presented in Table III-3. Annual groundwater pumping average 1,928,000 acre-feet per year, or 53,000 acre-feet per year more than under the No-Action Alternative. Like Alternative 1, the variation in groundwater pumping is very similar to the No-Action Alternative. Average annual groundwater pumping is slightly higher than Alternative 1. This is caused by economic incentive to replace acreage in the San Joaquin River Region retired due to water acquisitions (see Attachment A for additional information). Annual groundwater recharge (total) averaged 1,894,000 acre-feet per year, or 45,000 acre-feet per year more than under the No-Action Alternative. Like Alternative 1, the annual variation in recharge is very similar to the No-Action Alternative. Changes in groundwater storage for Alternative 2 are also very similar to Alternative 1.

Groundwater Levels

Differences in groundwater levels under Alternative 2 from the No-Action Alternative for the end of the 69-year simulation period are shown in Figure III-29b for the San Joaquin River Region (in feet above mean sea level). Regional groundwater conditions are generally similar to the No-Action Alternative. One difference occurs in the vicinity of the San Joaquin River basin tributaries where increased streamflows associated with acquired water would result in groundwater level increases relative to the No-Action Alternative. Lower groundwater levels, approximately 10 feet below the No-Action Alternative, developed along the eastern boundary of Merced County. Deep percolation of applied water from lands previously irrigated and now fallowed as a result of Alternative 2 water acquisitions, partly contributed to these groundwater level declines. In the southwestern corner (the DMC service area) of the region groundwater levels are lower than No-Action Alternative groundwater levels by more than 10 feet in a few locations. However, in an isolated case, groundwater levels are approximately 10 feet above the No-Action Alternative groundwater level. This is likely a response to increased refuge supplies in this alternative. On a regional basis under Alternative 2 the hydraulic connection between streams and underlying groundwater tables is similar to the No-Action Alternative.

Land Subsidence

Land subsidence impacts in the San Joaquin River Region for Alternative 2 as compared to the No-Action Alternative, shown in Figure III-30, are similar to Alternative 1.

Groundwater Quality

Under Alternative 2, with groundwater levels declining primarily along the west side of the San Joaquin River Region, it is expected that regional groundwater quality in the San Joaquin River Region would not change in comparison to the No-Action Alternative.

Agricultural Subsurface Drainage

Under Alternative 2, changes to agricultural subsurface drainage conditions would be similar to Alternative 1.

Seepage and Waterlogging

Increases in groundwater levels occur near areas of the San Joaquin River that have historically been sensitive to seepage-induced waterlogging problems. However, a comparison of flows in the San Joaquin River at Vernalis under Alternative 2 and the No-Action Alternative, shown in Figure III-31, indicates no discernable differences. Based on this analysis, seepage problems to low-lying farm lands along the lower reaches of the San Joaquin River are not expected to differ from the No-Action Alternative.

TULARE LAKE REGION

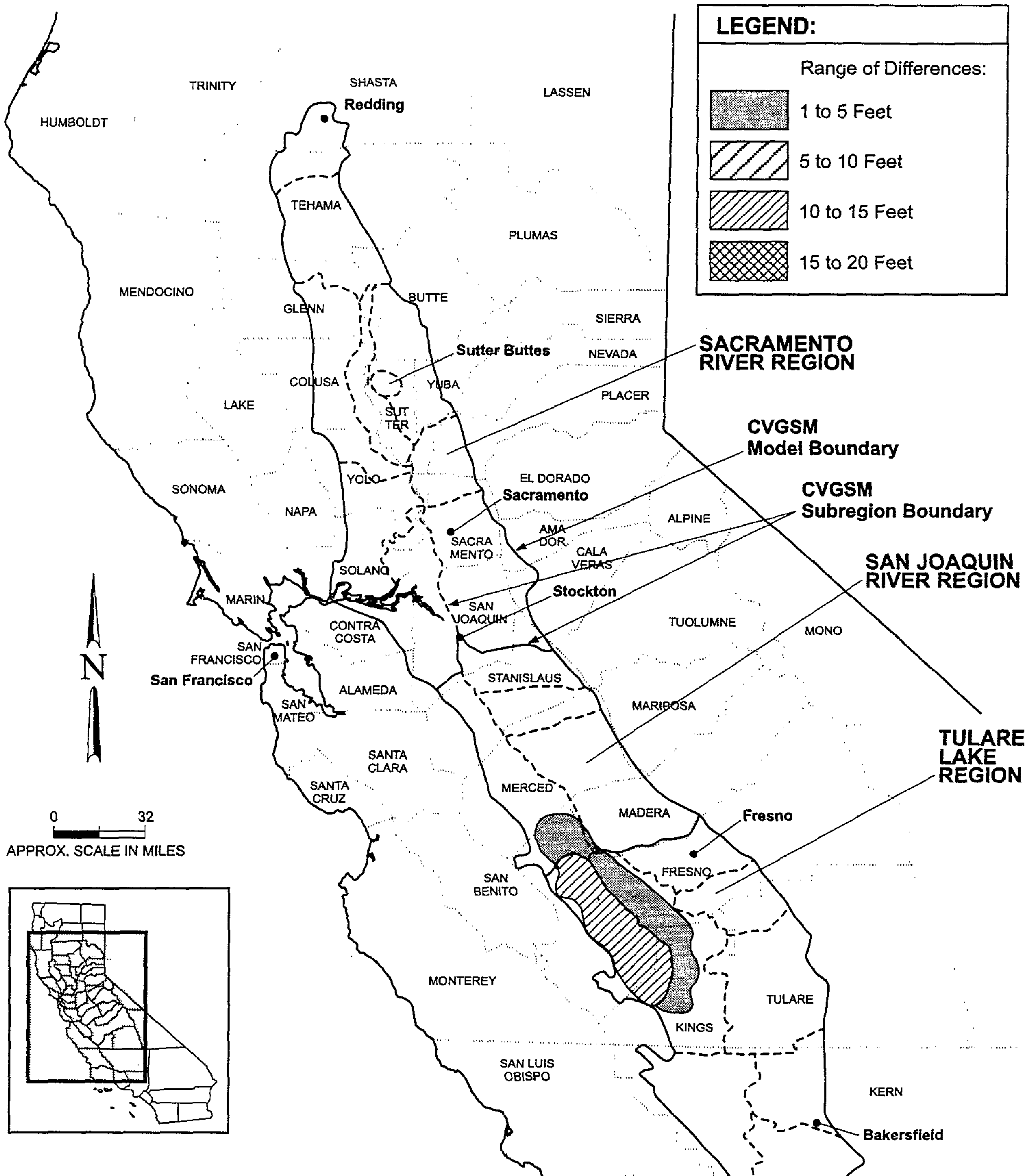
As in the San Joaquin River Region, changes in groundwater conditions under Alternative 2 in the Tulare Lake Region are similar to Alternative 1 on a regional basis. However, additional groundwater storage declines would result and a larger area of the west side of the region would be affected by land subsidence.

Groundwater Storage and Production

Under Alternative 2, groundwater conditions associated with the north and south subareas of the Tulare Lake Region are similar to Alternative 1, and only a small increase in groundwater storage depletion would occur.

Groundwater Levels

Differences in groundwater levels for the Tulare Lake Region at the end of the 69-year simulation period as compared to the No-Action Alternative, shown in Figure III-29c, are similar to differences described under Alternative 1.



Footnote:
Difference based on land subsidence occurring over the simulation period between Alternative 2 and the No-Action Alternative (Alternative 2 minus the No-Action Alternative). Values averaged over portions of CVGSM model subregions exhibiting land subsidence.

FIGURE III-30

REGIONAL DIFFERENCES IN SIMULATED LAND SUBSIDENCE IN ALTERNATIVE 2 FROM NO-ACTION ALTERNATIVE

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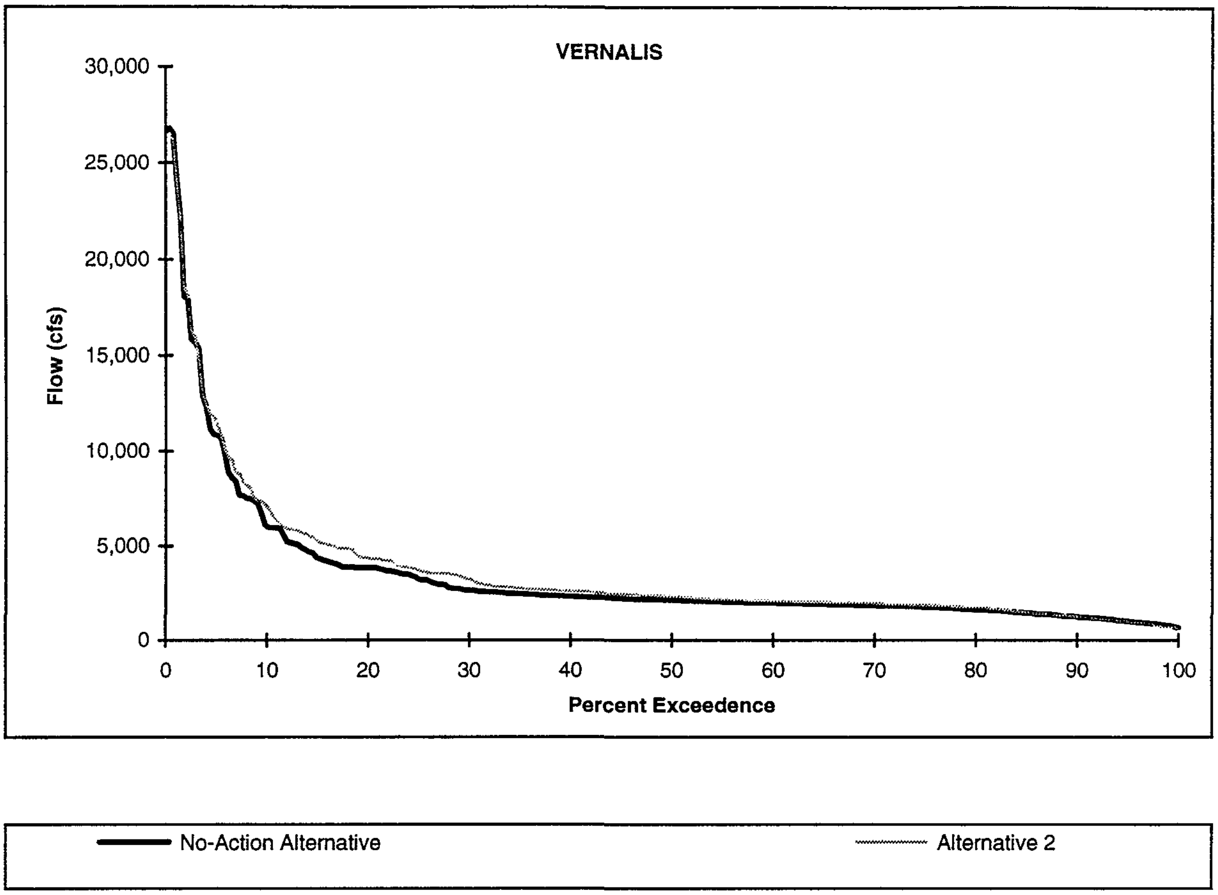

FIGURE III-31
SIMULATED SAN JOAQUIN RIVER FLOWS (MAY THROUGH AUGUST) FOR ALTERNATIVE 2 AS COMPARED TO NO-ACTION ALTERNATIVE

Land Subsidence

Additional groundwater level declines observed in Alternative 2 in comparison to the No-Action Alternative resulted in land subsidence along the west side of the Tulare Lake Region (North). Figure III-30 shows the range of differences in land subsidence occurring over the simulation period between Alternative 2 and the No-Action Alternative. The range of differences along the west side is between 10 and 15 feet. The range in differences decreases to 1 to 5 feet towards the axis of the Central Valley. This areal extent of potential land subsidence is slightly larger than Alternative 1.

Groundwater Quality

Under Alternative 2, groundwater quality associated with the north and south subareas of the Tulare Lake Region are similar to Alternative 1.

Agricultural Subsurface Drainage

Under Alternative 2, groundwater levels associated with the north and south subareas of the Tulare Lake Region are similar to Alternative 1, and potential improvements to agricultural subsurface drainage conditions in comparison to the No-Action Alternative would be similar to Alternative 1.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with streamflows and adjacent high groundwater tables in the Tulare Lake Region, and none of the options associated with Alternative 2 would initiate any seepage problem in comparison to the No-Action Alternative.

SAN FRANCISCO BAY REGION

Changes in CVP deliveries to the San Francisco Bay Region would be the same as in Alternative 1. Impacts to groundwater resources as compared to the No-Action Alternative would be similar to those described for Alternative 1.

ALTERNATIVE 3

Alternative 3 assumes greater water acquisitions than Alternative 2 on the Stanislaus, Tuolumne, and Merced rivers, and attempts to acquire water from willing sellers on the Calaveras, Mokelumne, and Yuba rivers. Another key distinction of Alternative 3 from Alternative 2 is the assumption that the acquired water, once reaching the Delta, can be repumped as export deliveries out of the Delta. The groundwater analysis of Alternative 3 assumes groundwater pumping would be reduced in the event imported surface water supplies increased. The increased acquired water quantities also result in changes in crop mix and crop acreage, and irrigation technology. The groundwater analysis incorporates this information in the form of crop acreage and demands, and irrigation efficiencies. All remaining assumptions underlying this analysis are the same as those for Alternative 1 and 2.

SACRAMENTO RIVER REGION

Differences in groundwater levels for Alternative 3 as compared to the No-Action Alternative are shown in Figure III-32a. Along the east side of the Sacramento Valley some groundwater level increases would occur as seepage increased from streams benefiting from acquired water. In areas of fallowed land resulting from water acquisitions, local groundwater levels would decline as compared to the No-Action Alternative as deep percolation of applied water decreased. Groundwater levels in areas along the west side changed very little as compared to the No-Action Alternative.

Groundwater Storage and Production

Sacramento River Region (West). Average annual groundwater conditions for the Sacramento River Region (West) under Alternative 3 are presented in Table III-1. Annual variations for groundwater pumping, recharge, and storage are presented in Figures III-2 and III-3. As indicated by these figures, Alternative 3 groundwater conditions are similar to Alternative 2. Small decreases in groundwater pumping in comparison to Alternative 1 occurred as a result of small increases in CVP surface water deliveries in this region.

Sacramento River Region (East). Average annual groundwater conditions for the Sacramento River Region (East) under Alternative 3 are presented in Table III-2. For the east side an increase in groundwater pumping, drawing groundwater levels down, combined with increased streams flows associated with acquired water resulted in greater stream seepage to groundwater in comparison to No-Action Alternative. The increased pumping in this area is caused by economic incentive to replace acreage in the San Joaquin River Region retired due to water acquisitions. These changes in the groundwater balance along the east side result in groundwater storage declines larger in comparison to the No-Action Alternative, as shown in Figure III-5.

Groundwater Levels

Differences in the groundwater levels for the end of the 69-year simulation for Alternative 3 are shown in Figure III-32a. Groundwater conditions for the west side of the Sacramento River Region would be similar to the No-Action Alternative. Groundwater levels in the southeastern portion of the Sacramento River Region in comparison to the No-Action Alternative would increase over the long-term approximately 5 to 10 feet on a regional basis, primarily as a result of increased stream seepage from acquired water on the Calaveras River. Acquired water averaging approximately 27,000 acre-feet per year, formerly diverted at Belota, now passes this diversion point and travels the length of the remaining river reach. Decreases in long-term groundwater levels of approximately 10 to 20 feet would occur on a regional basis in some areas along the east side from north of the Sutter Buttes to south of the City of Sacramento. This decrease would occur as a result of reduced deep percolation due to land fallowing associated with the acquisition of water, and increased groundwater pumping.

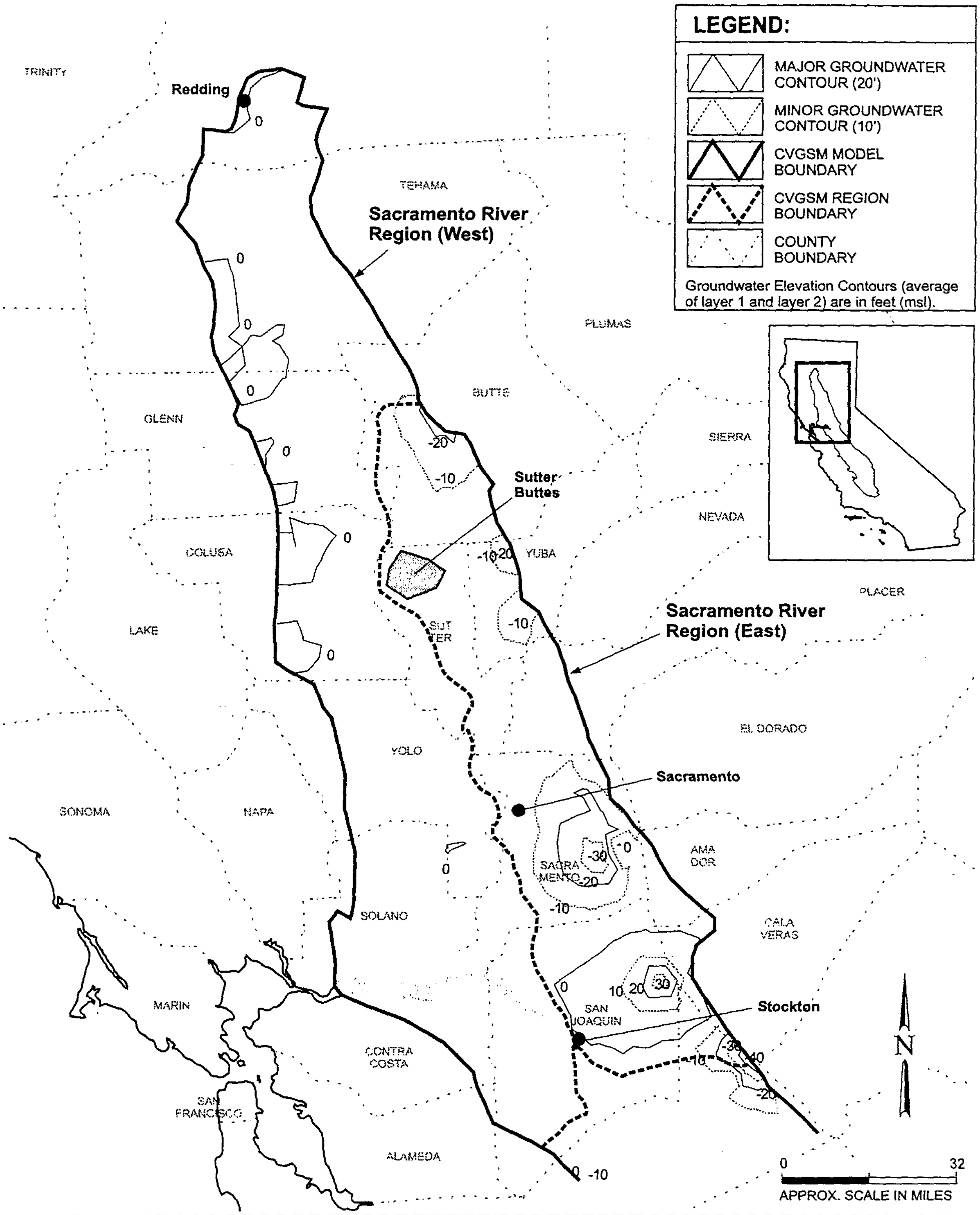

FIGURE III-32a
SACRAMENTO RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 3 AS COMPARED TO THE NO-ACTION ALTERNATIVE

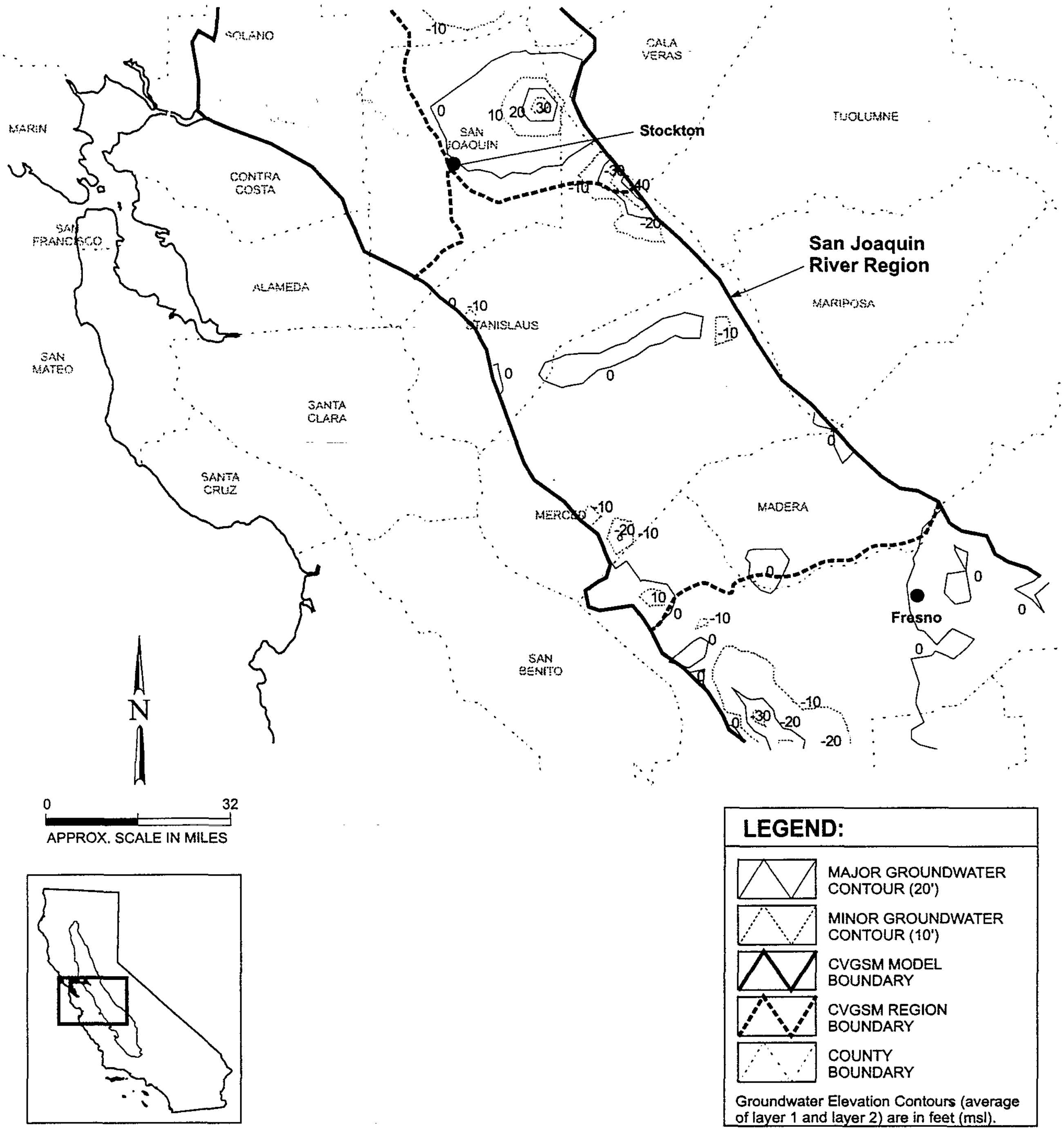

FIGURE III-32b
SAN JOAQUIN RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 3 AS COMPARED TO THE NO-ACTION ALTERNATIVE

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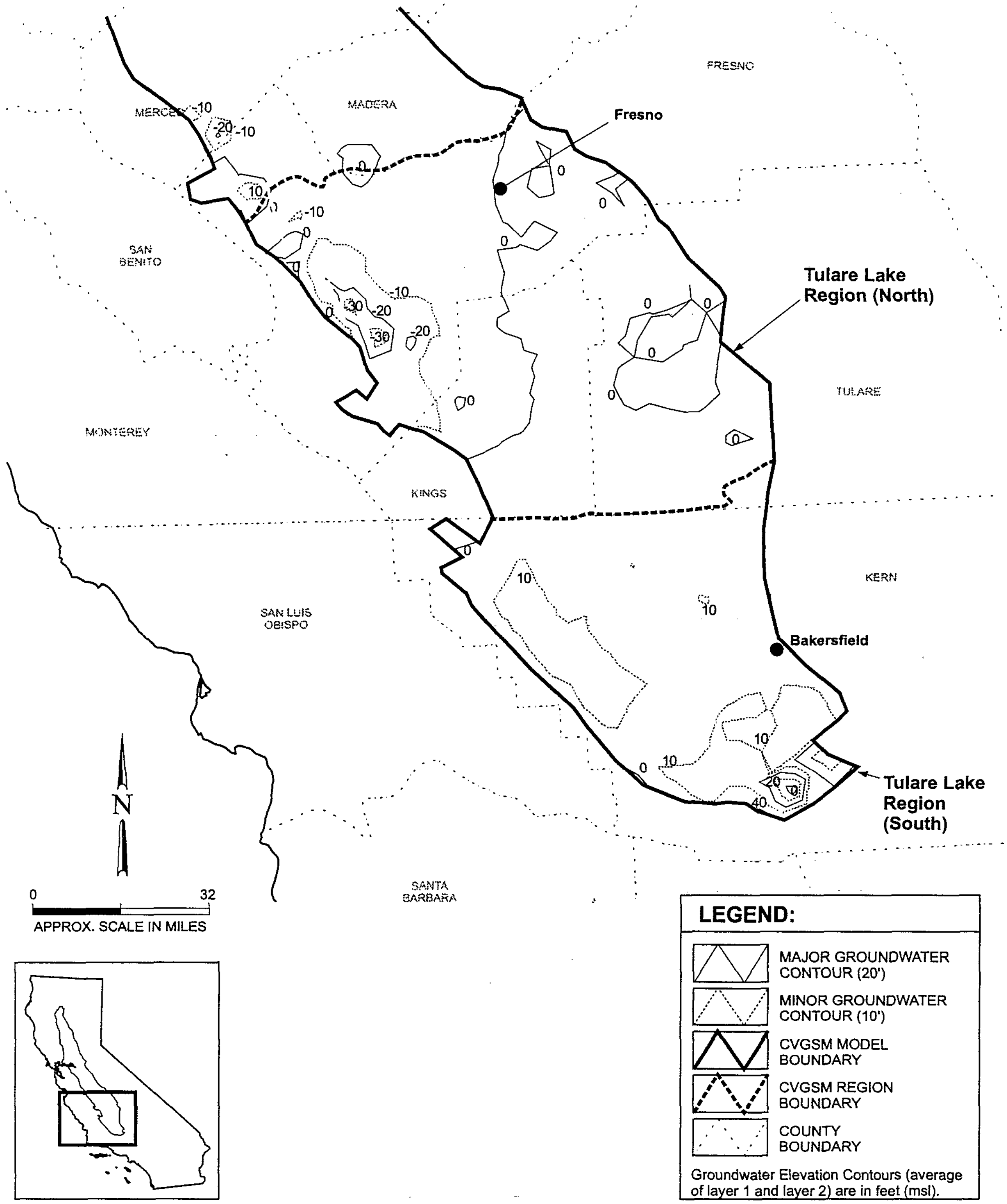

FIGURE III-32c
TULARE LAKE REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 3 AS COMPARED TO THE NO-ACTION ALTERNATIVE

Land Subsidence

Under Alternative 3, with groundwater levels declining very little in areas subject to land subsidence, no additional land subsidence in comparison to the No-Action Alternative would occur.

Groundwater Quality

Under Alternative 3, with groundwater levels declining very little in areas subject to poor groundwater quality, it is expected that groundwater quality conditions in the Sacramento River Region would not change in comparison to the No-Action Alternative.

Agricultural Subsurface Drainage

Under Alternative 3, with groundwater levels declining very little in areas subject to poor subsurface drainage conditions, it is expected that agricultural subsurface drainage problems in the Sacramento River Region would not change in comparison to the No-Action Alternative.

Seepage and Waterlogging

Sacramento River summer flows are the similar to Alternative 1. See the Alternative 1 seepage impact assessment.

SAN JOAQUIN RIVER REGION

CVP deliveries to this region would increase relative to Alternative 1 and 2 due to the ability to repump acquired water as it flows through the Delta. Groundwater pumping would decrease, and groundwater levels would increase for Alternative 3 as compared to Alternatives 1 and 2 in areas of the San Joaquin River Region receiving these deliveries. Long-term groundwater levels are still lower than the No-Action Alternative.

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under Alternative 3 are presented in Table III-3. Groundwater conditions for the San Joaquin River Region would be similar to Alternative 2, but for different reasons. In comparison to Alternative 2, Alternative 3 indicates less deep percolation from conveyance seepage. This is a result of reduced deliveries associated with water acquisitions. On the contrary, Alternative 3 exhibits more recharge from stream seepage and subsurface flow from adjacent regions to the northeast, both a result of higher flows on streams with acquired water. Changes in groundwater storage in the San Joaquin River Region for Alternative 3 are shown in Figures III-7 and III-8. The net change in groundwater storage over the 69-year simulation period is -2,530,000 acre-feet, which is 671,000 acre-feet more groundwater depletion than the No-Action Alternative.

Groundwater Levels

Differences in San Joaquin River Region groundwater levels for the end of the 69-year simulation are shown in Figure III-32b. Regional groundwater levels are similar to Alternative 2 in the northern half and eastern side of the region. However, in the southwestern corner of the region, where changes in recharge due to water acquisition dynamics are minimal, Alternative 3 groundwater levels would decline more than Alternative 2 in comparison to the No-Action Alternative due to greater groundwater pumping. The increased pumping in this part of the region would be caused by economic incentives, driving the crop market towards replacing acreage retired on the east side of the San Joaquin River Region due to water acquisitions. The regional similarities in groundwater levels of Alternatives 3 in comparison to Alternative 2 along the east side of the region indicate that the hydraulic connection between streams and underlying groundwater tables would also be similar to Alternative 2.

Land Subsidence

Land subsidence impacts associated with the San Joaquin River Region for Alternative 3, relative to the No-Action Alternative, are shown in Figure III-33. Because groundwater level declines in areas subject to land subsidence are smaller in comparison to Alternative 1, the area affected by potential increased land subsidence is also smaller than Alternative 1.

Groundwater Quality

Under Alternative 3, with groundwater levels declining very little in this area, it is expected that groundwater quality in the San Joaquin River Region would not change in comparison to the No-Action Alternative.

Agricultural Subsurface Drainage

Under Alternative 3, changes to agricultural subsurface drainage conditions would be similar to Alternative 1.

Seepage and Waterlogging

Figure III-34 compares exceedence levels for summer flows in the San Joaquin River at Vernalis under Alternative 3 and the No-Action Alternative. The 14,000 cfs exceedence level increases from about 4 percent to around 5 percent. In addition, groundwater levels nears areas of the San Joaquin River subject to seepage-induced waterlogging would increase slightly over the long-term, and waterlogging of adjacent low-lying farm lands along the lower reaches of the San Joaquin River and its tributaries could be expected to occur.

TULARE LAKE REGION

The opportunity to repump acquired water from the Delta improved average annual CVP and SWP deliveries to the region as compared to Alternatives 1 and 2. Long-term groundwater levels declines under Alternative 3 as compared to the No-Action Alternative would not be as great as Alternatives 1 and 2.

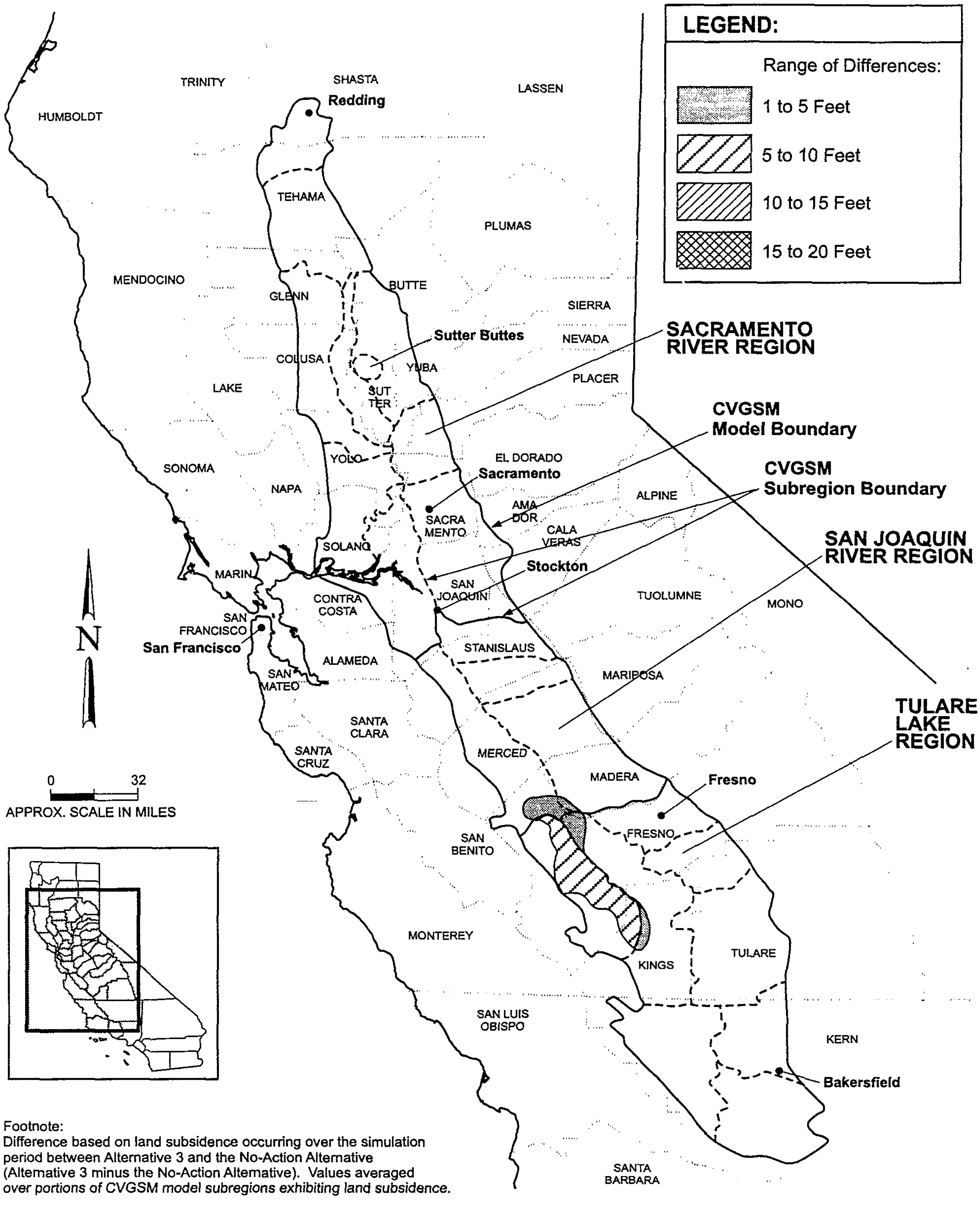

FIGURE III-33

REGIONAL DIFFERENCES IN SIMULATED LAND SUBSIDENCE IN ALTERNATIVE 3 FROM NO-ACTION ALTERNATIVE

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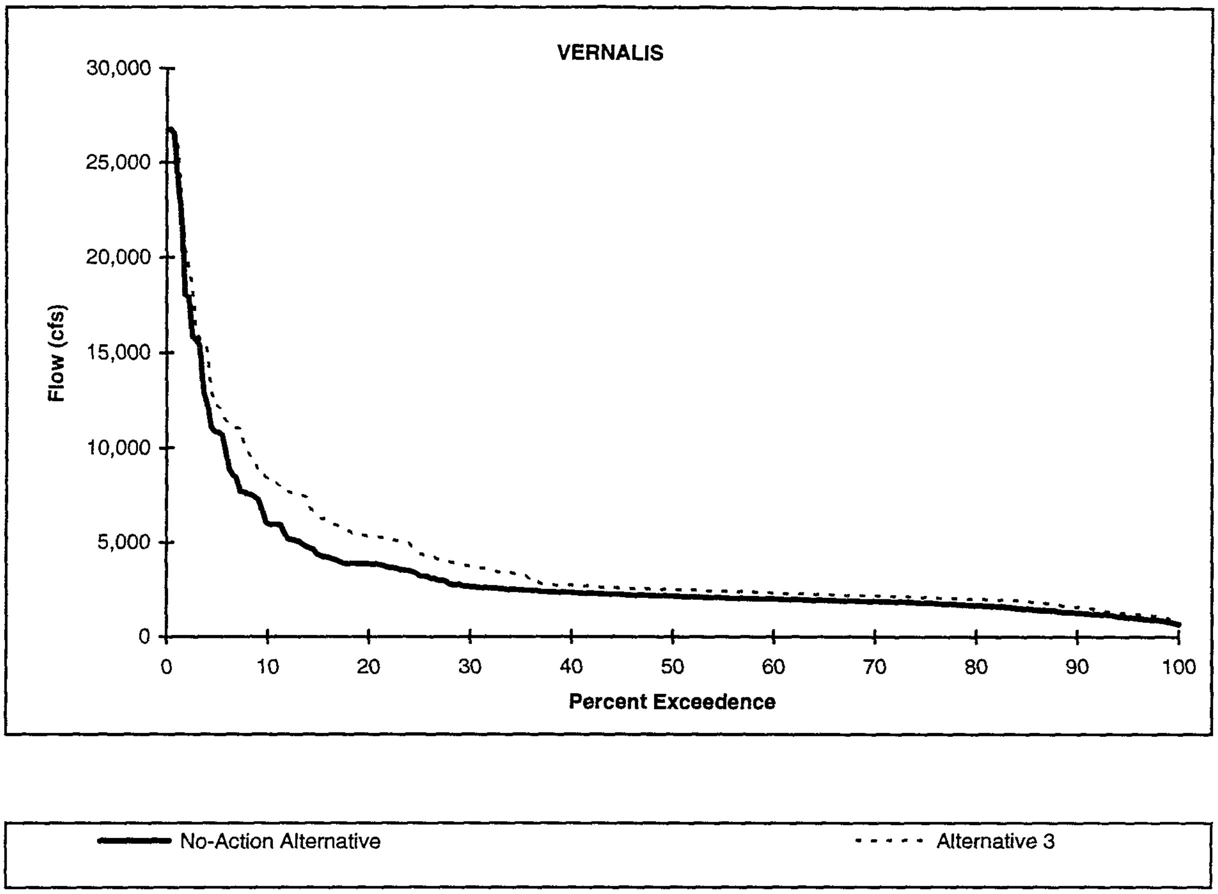

FIGURE III-34
SIMULATED SAN JOAQUIN RIVER FLOWS (MAY THROUGH AUGUST) FOR ALTERNATIVE 3 AS COMPARED TO NO-ACTION ALTERNATIVE

Groundwater Storage and Production

Tulare Lake Region (North). Recharge conditions in the Tulare Lake Region (North), shown in Table III-4 for Alternative 3, are very similar to the No-Action Alternative. Groundwater storage declines of magnitudes similar to those observed in Alternatives 1 and 2 would be avoided here, however, due to a smaller increase in groundwater pumping, 14,000 acre-feet per year, in comparison to the No-Action Alternative. Groundwater pumping would be reduced as a result of increased CVP deliveries to the west side of this region. The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative (Figure III-10). The net change in groundwater storage is -17,596,000 acre-feet, or an increase in groundwater depletion of 806,000 acre-feet in comparison to the No-Action Alternative. This long-term groundwater storage decline is less than Alternative 1 by 2,810,000 acre-feet.

Tulare Lake Region (South). Average annual groundwater conditions for the Tulare Lake Region (South) under Alternative 3 are presented in Table III-5. Annual groundwater pumping averaged 1,337,000 acre-feet per year, or 74,000 acre-feet per year less than under the No-Action Alternative, and 43,000 acre-feet per year less than under Alternative 1. Groundwater pumping is less in Alternative 3 because of increased SWP deliveries. SWP Delta exports increase due to the assumption that acquired water can be exported. Annual groundwater recharge (total) averaged 1,490,000 acre-feet per year, or 39,000 acre-feet per year less than the No-Action Alternative, and 23,000 acre-feet per year less than Alternative 1. The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative (Figure III-11). Long-term groundwater conditions are improved, as shown in Figure III-12. The net change in groundwater storage over the 69-year simulation period is 10,562,000 acre-feet, 2,435,000 acre-feet increase in groundwater storage than the No-Action Alternative, and 1,363,000 acre-feet more than Alternative 1.

Groundwater Levels

Differences in Tulare Lake Region groundwater levels for the end of the 69-year simulation for Alternative 3 are shown in Figure III-32c. Groundwater levels would be lower in comparison to the No-Action Alternative along the west side of the region, with differences exceeding 30 feet.

This is primarily due to increased groundwater pumping in response to a reduction in imported CVP supplies. However, the decline in groundwater levels in this area is smallest under this alternative in comparisons to all other alternatives due to the assumption that acquired water passing through the Delta can be repumped. This assumption is also responsible for the higher groundwater levels observed in the southern end of Tulare Lake Region in comparison to the No-Action Alternative. SWP deliveries to this area would increase under Alternative 3 in comparison to the No-Action Alternative. There is little difference in groundwater levels along the east side of the Tulare Lake Region, and stream-groundwater interaction would be similar under Alternative 3 as compared to the No-Action Alternative.

Where confined conditions of layer 2 exist, average differences in groundwater levels between Alternative 3 and the No-Action Alternative are up to 5 feet more than the average difference based on layer 1 and layer 2 average groundwater levels.

Land Subsidence

Additional declines in groundwater levels observed in Alternative 3 in comparison to the No-Action Alternative indicates that additional land subsidence greater than 5 feet would occur along the west side of the Tulare Lake Region (North), as shown in Figure III-33. Similar to Alternative 1, the area of land subsidence surrounds major conveyance facilities including the DMC and the California Aqueduct; however, the smaller groundwater level declines in this area would lead to a smaller area of these aqueducts being subject to land subsidence under Alternative 3 in comparison to the other alternatives.

Groundwater Quality

Lower groundwater levels in relation to No-Action Alternative could possibly cause additional upwelling of poor-quality groundwater into productive groundwater zones. In comparison to other alternatives, however, the potential upwelling could be less severe.

Agricultural Subsurface Drainage

Under Alternative 3, the smaller decline in groundwater levels along the west side of the Tulare Lake Region could result in a smaller improvement of drainage conditions in comparison to the other alternatives. The increase in groundwater levels in the southern portion of the region in comparison to the No-Action Alternative could possibly hinder agricultural subsurface drainage in this area.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with streamflows and adjacent high groundwater tables in the Tulare Lake Region, and none of the options associated with Alternative 3 would initiate any seepage problem in comparison to the No-Action Alternative.

SAN FRANCISCO BAY REGION

Under Alternative 3, CVP deliveries to Santa Clara and San Benito counties would decrease on average 10,000 acre-feet per year relative to the No-Action Alternative. Local regulation of groundwater extraction by means of pump taxes, such as those levied by the SCVWD, would discourage replacement of this CVP water with groundwater. For the purposes of this programmatic level of analysis it is assumed that any increase in groundwater pumping to offset these reduced CVP deliveries would be minimal. A small impact to groundwater conditions could occur in the vicinity of spreading basins as a result of lost deep percolation associated with the reduced CVP deliveries.

Under Alternative 3 CVP deliveries to Alameda and Contra Costa counties would be similar to the No-Action Alternative. Under these conditions no net impact to groundwater storage, levels, and quality would occur, and no additional land subsidence would occur in these areas.

ALTERNATIVE 4

Alternative 4 combines the effects of using (b)(2) water for in-Delta purposes with the elements of acquired water from willing sellers assumed in Alternative 3. However, as in Alternative 2, the acquisition water (b)(3) was not allowed to be repumped as exports once reaching the Delta. Under this condition groundwater pumping would increase as SWP and CVP deliveries are reduced, as long as economically feasible. All remaining assumptions underlying this analysis are the same as those for Alternatives 1, 2, and 3.

SACRAMENTO RIVER REGION

Differences in Sacramento River Region groundwater levels for the end of the 69-year simulation period for Alternative 4 are shown in Figure III-35a. Groundwater conditions for this area would be similar to those described under Alternative 3.

SAN JOAQUIN RIVER REGION

Differences in San Joaquin River Region groundwater levels for the end of the 69-year simulation period for Alternative 4 are shown in Figure III-35b. Groundwater conditions for this area would be similar to those described under Alternative 3 in the northern half of the region. However, in the south half, where CVP supplies are delivered, groundwater levels would decline, relative to the No-Action Alternative, in response to reduced CVP deliveries due to (b)(2) water in the Delta.

Groundwater Storage and Production

Average annual groundwater conditions for the San Joaquin River Region under Alternative 4 are presented in Table III-3. Groundwater storage conditions declined in comparison to the No-Action Alternative as a result of increased groundwater pumping. This occurred due to decreased CVP deliveries, relative to the No-Action Alternative, in response to the use of additional (b)(2) water for Delta needs.

Groundwater Levels

Differences in the groundwater levels under Alternative 4 for the end of the 69-year simulation would be similar to Alternative 3 in the north half of the region (see Figure III-35b). In the southern half of the region, groundwater levels under Alternative 4 would be lower than Alternative 3, and are lower than the No-Action Alternative by approximately 5 feet regionally, and by 10 feet in several locations in central Madera County and northwestern Fresno County. These additional declines would occur in response to increased groundwater pumping and increased subsurface flow south towards declining groundwater levels in the Tulare Lake Region. Groundwater conditions in the north half of the region with regards to the hydraulic connection with streams would be similar to Alternative 3. The interaction of surface water with underlying groundwater in the southeastern portion of the region would be impacted as a result of declining groundwater levels, and would result in greater stream losses in this area.

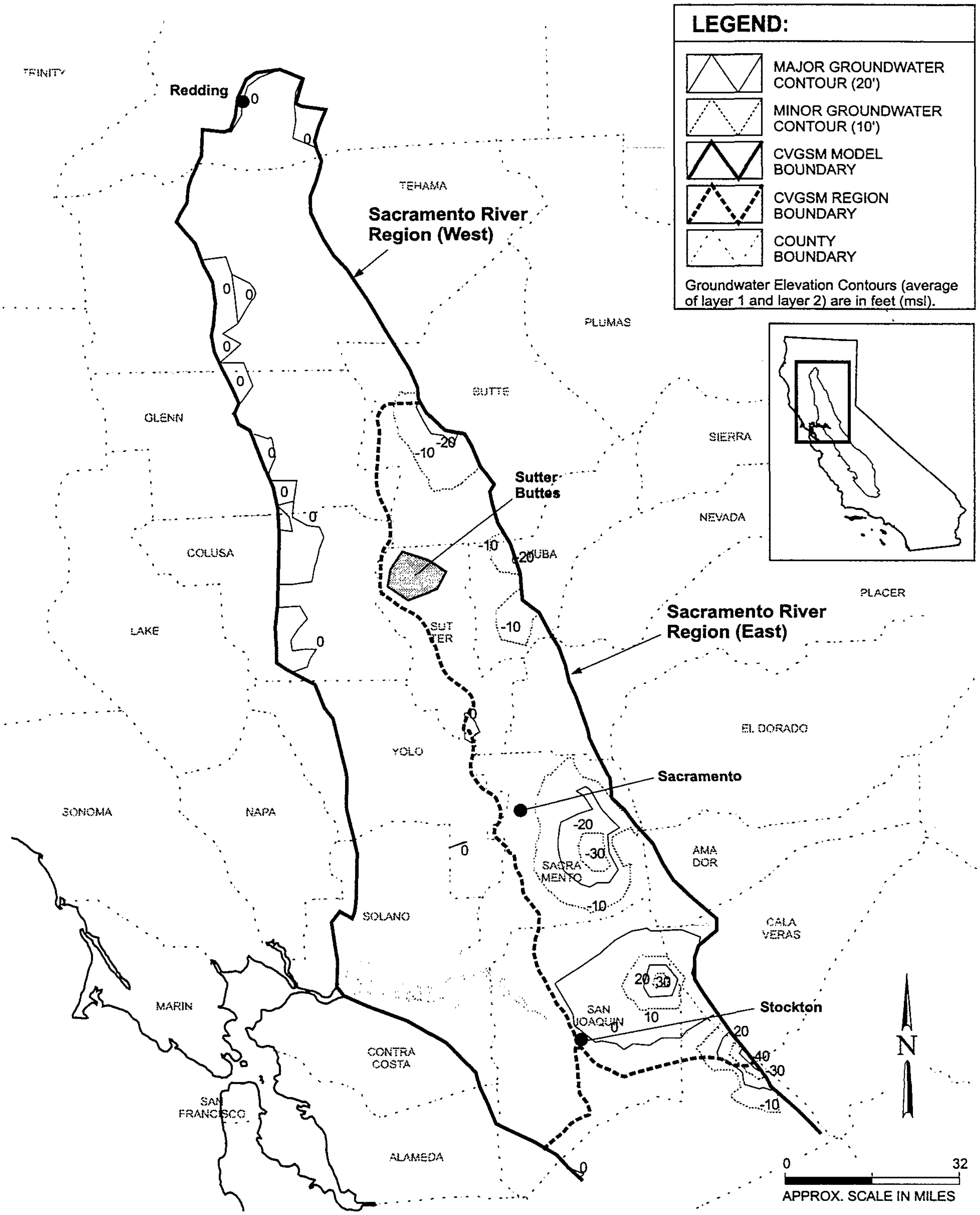

FIGURE III-35a
SACRAMENTO RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 4 AS COMPARED TO THE NO-ACTION ALTERNATIVE

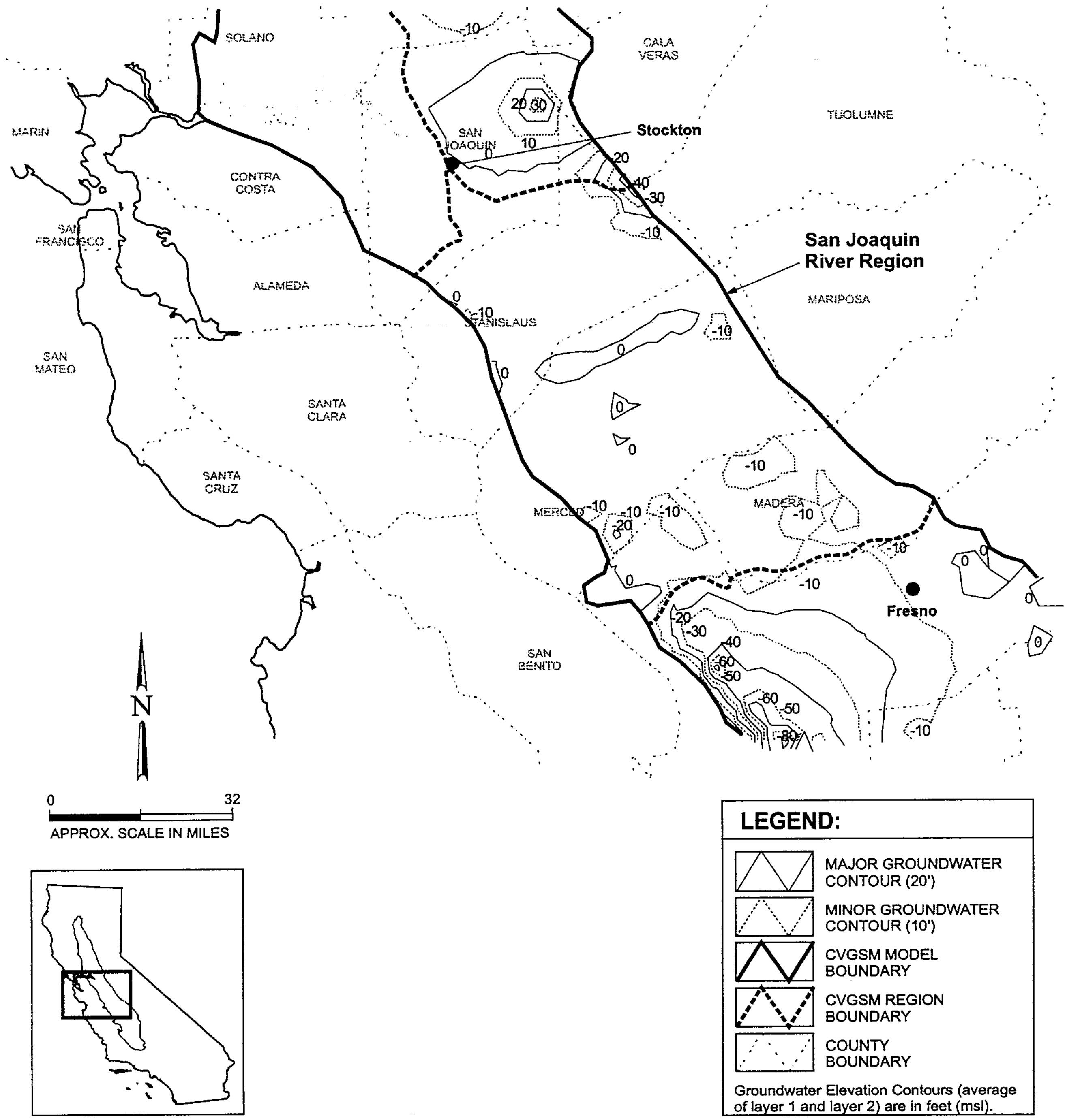

FIGURE III-35b
SAN JOAQUIN RIVER REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 4 AS COMPARED TO THE NO-ACTION ALTERNATIVE

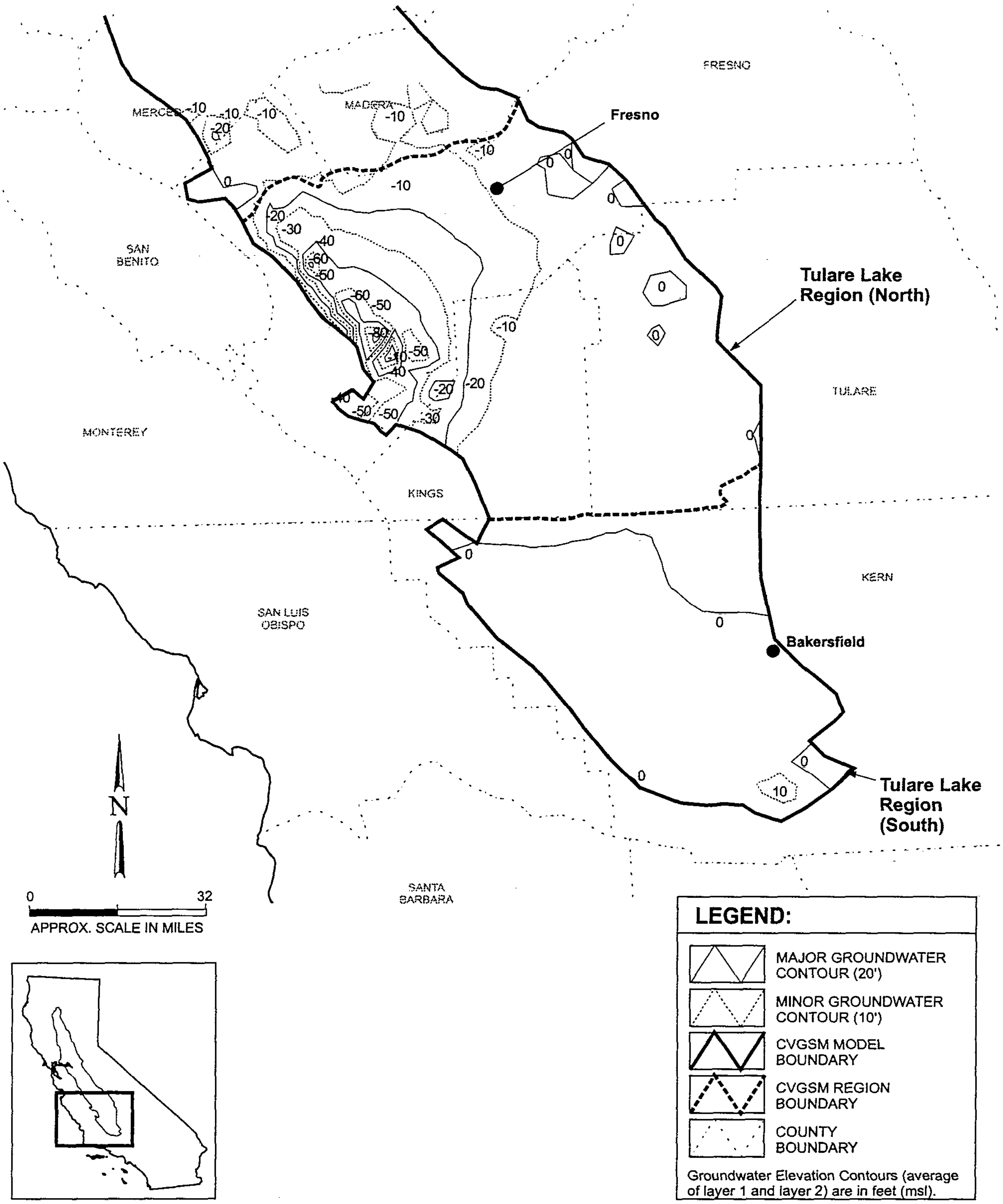

FIGURE III-35c
TULARE LAKE REGION DIFFERENCES IN END OF SIMULATION GROUNDWATER ELEVATIONS (SEPTEMBER 1990) FOR ALTERNATIVE 4 AS COMPARED TO THE NO-ACTION ALTERNATIVE

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Land Subsidence

In the south half of the region, impacts in the form of land subsidence would be similar to Alternative 1, as shown in Figure III-36.

Groundwater Quality

Groundwater level declines in Madera County, as compared to the No-Action Alternative, would possibly result in migration of poor quality groundwater, reported to contain elevated levels of nitrates in this area, into areas of better quality groundwater.

Agricultural Subsurface Drainage

Under Alternative 4, changes to agricultural subsurface drainage conditions would be similar to Alternative 1.

Seepage and Waterlogging

Impacts in the form of seepage-induced waterlogging would be similar to Alternative 3.

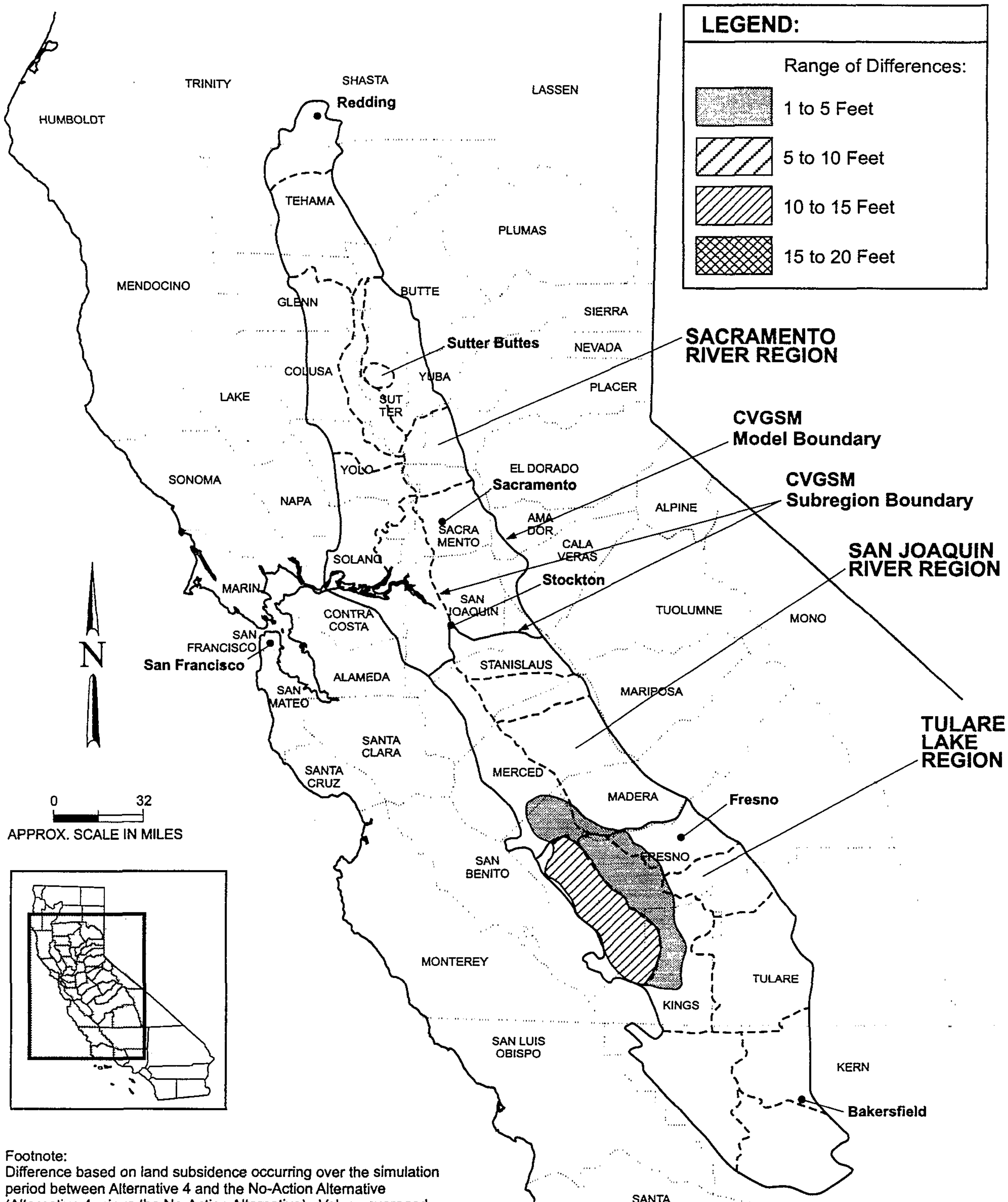
TULARE LAKE REGION

The (b)(2) water assumed to meet certain Delta needs in this region would result in additional Delta export limitations in comparison to the No-Action Alternative. Differences in Tulare Lake Region groundwater levels for the end of the 69-year simulation period for Alternative 4 are shown in Figure III-35c. Groundwater levels would decline greatest in areas served by these CVP supplies. Groundwater pumping would attempt to make up any differences associated with reduced CVP and SWP surface water deliveries, as long as economically feasible.

Groundwater Storage and Production

Tulare Lake Region (North). Recharge conditions in the Tulare Lake Region (North), shown in Table III-4 for Alternative 4, are very similar to Alternative 1. Groundwater storage declines of magnitudes larger than those observed in Alternatives 1, 2 and 3 would occur however due to an increase in groundwater pumping, 119,000 acre-feet per year, in comparison to the No-Action Alternative. This increase in groundwater pumping is due primarily to additional requirements of (b)(2) water for Delta needs, resulting in reductions in CVP deliveries to the west side of this region. The annual variation in groundwater pumping and recharge is very similar to the No-Action Alternative (Figure III-10). The net change in groundwater storage is -21,778,000 acre-feet, or an increase in groundwater depletion of 4,988,000 acre-feet in comparison to the No-Action Alternative, and 1,372,000 acre-feet more storage decline than Alternative 1.

Tulare Lake Region (South). Average annual groundwater conditions for the Tulare Lake Region (South) under Alternative 4 are presented in Table III-5. Recharge conditions in this area are also similar to Alternative 1. Annual groundwater pumping averaged 1,395,000 acre-feet per year, or 16,000 acre-feet per year less than under the No-Action Alternative, and 15,000 acre-feet per year more than Alternative 1. Increases in groundwater pumping beyond Alternative 1 are



Footnote:
Difference based on land subsidence occurring over the simulation period between Alternative 4 and the No-Action Alternative (Alternative 4 minus the No-Action Alternative). Values averaged over portions of CVGSM model subregions exhibiting land subsidence.

FIGURE III-36

REGIONAL DIFFERENCES IN SIMULATED LAND SUBSIDENCE IN ALTERNATIVE 4 FROM NO-ACTION ALTERNATIVE

primarily a result of reduced CVP deliveries due to additional export restrictions associated with (b)(2) needs for the Delta. Long-term groundwater storage conditions increase slightly in comparison to the No-Action Alternative as a result of decreases in groundwater pumping, increasing over the 69-year simulation period by 610,000 acre-feet.

Groundwater Levels

Under Alternative 4, differences in groundwater levels for the 69-year simulation period as compared to the No-Action Alternative are shown in Figure III-35c. Regional differences in long-term groundwater levels are similar to those observed in Alternative 1; however, the additional groundwater pumping in response to reduced CVP deliveries would result in maximum groundwater level declines of 10 to 20 feet greater in these areas.

Where confined conditions of layer 2 exist, average differences in groundwater levels between Alternative 4 and the No-Action Alternative are 5 to 10 feet more than the average difference based on layer 1 and layer 2 average groundwater levels.

Land Subsidence

The potential for additional land subsidence in comparison to the No-Action Alternative is similar to Alternative 1. It is likely that a small increase in the area affected by land subsidence would occur, as shown in Figure III-36.

Groundwater Quality

Under Alternative 4, groundwater quality associated with the north and south subareas of the Tulare Lake Region is similar to Alternative 1.

Agricultural Subsurface Drainage

Under Alternative 4, agricultural subsurface drainage associated with the north and south subareas of the Tulare Lake Region is similar to Alternative 1.

Seepage and Waterlogging

There are no regional seepage-induced waterlogging problems associated with streamflows and adjacent high groundwater tables in the Tulare Lake Region, and none of the options associated with Alternative 4 would initiate any seepage problem in comparison to the No-Action Alternative.

SAN FRANCISCO BAY REGION

Under Alternative 4, CVP deliveries to Santa Clara and San Benito counties would decrease on average 20,000 acre-feet per year relative to the No-Action Alternative. Local regulation of groundwater extraction by means of pump taxes, such as those levied by the SCVWD, would discourage replacement of this CVP water with groundwater. For the purposes of this programmatic level of analysis it is assumed that any increase in groundwater pumping to offset these reduced CVP deliveries would be minimal. A small impact to groundwater conditions could occur in the vicinity of spreading basins as a result of lost deep percolation associated with the reduced CVP deliveries.

Under Alternative 4 CVP deliveries to Alameda and Contra Costa counties would be similar to the No-Action Alternative. Under these conditions no net impact to groundwater storage, levels, and quality would occur, and no additional land subsidence would occur in these areas.

CHAPTER IV

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Chapter IV

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ATTACHMENT A

GROUNDWATER PUMPING IN PEIS ALTERNATIVES

C-080501

MEMORANDUM

Central Valley Project

ENVIRONMENTAL TEAM

To:	Gwen Buchholz	Date:	March 20, 1997
From:	Roger Putty Steve Hatchett	C.C.:	John Johannis Phil Sharpe David Moore
Subject:	Groundwater Pumping in PEIS Alternatives		

This memorandum addresses policy assumptions governing groundwater pumping in the PEIS alternatives and implementation of these assumptions in the technical analysis. The PEIS team agreed that a policy condition for acquiring water is that the acquired water not be replaced with groundwater pumping if Interior could prevent it. Because Interior does not have legislative authority to regulate groundwater in the State, the mechanism for achieving this policy goal is to be a term/condition in water acquisition contracts that Interior signs with willing sellers. A memorandum dated Feb. 28, 1996 stated:

> As a condition of the water acquisition, it is stipulated as a term/condition of the acquisition that no groundwater replacement pumping can occur in areas that are in overdraft or hydraulically connected to an adjacent waterway.

An implication of this approach to preventing groundwater replacement is that it applies only to the entities selling water to Interior.

Our intention for the technical analysis of Alternatives 2 through 4 was to limit the groundwater pumping to the Alternative 1 level, assuming that this would simulate the "no groundwater replacement" rule. However, two unanticipated results of the modeling analysis allowed modest increases in groundwater pumping over Alternative 1. The first result is that land retired due to water acquisitions created an economic incentive (through small increases in crop price) to replace the acreage in other regions. For example, retirement of hay production in the San Joaquin Basin increased the price of hay sufficiently to boost its acreage slightly in the Sacramento and Tulare Basins. The additional hay acreage demands more groundwater pumping in those areas. This is a logical result and is quite likely to happen in reality.

The second unanticipated result occurred because of slight differences in model data definition between CVGSM and CVPM. For example, CVGSM is simulated monthly for the 1922 to 1990 period; CVPM simulates a single year representing the average of 1922 to 1990. In addition, small differences in crop water requirements based on the difference in each models' representation of agricultural demands exist. These subtle modeling differences resulted in some regions experiencing slightly higher agricultural groundwater pumping in CVGSM than estimated by CVPM, even for the same crop mix, resulting in groundwater pumping "slack" between the two models. Since CVGSM's Alternative 1 simulated groundwater pumping served as the upper limit for starting the CVPM analyses of a given alternative, CVPM was able to make use of some of this "slack" (unused but available groundwater). In addition, a small amount of groundwater pumping "slack" was created in some regions during the second iteration.

Table 1 lists (by CVGSM/CVPM subregion) the No-Action Alternative average annual groundwater pumping for municipal & industrial demands, agricultural demands, and total groundwater pumping. The model subregions and their descriptions are shown in Figure 1. Tables 2a and 2b summarize, respectively, the average annual agricultural groundwater pumping for Alternatives 1 through 4, and Alternatives 2 through 4 differences in agricultural groundwater pumping from Alternative 1. The positive differences in Table 2b indicate that groundwater pumping increased in the alternative above that occurring in Alternative 1. The largest differences (in taf) are 12, 33, and 33 in alternatives 2, 3, and 4 respectively. These are differences in agricultural groundwater pumping, and are less than 5 percent of the total groundwater pumping occurring in their respective subregions. Increases above Alternative 1 agricultural groundwater pumping for the Sacramento, San Joaquin, and Tulare regions are less than 3 percent of the total Alternative 1 groundwater pumping occurring in each of these regions. For the entire Central Valley increases are less than 2 percent of the total Alternative 1 groundwater pumping.

The differences reported in Table 2b are not easily discernible. For Alternatives 2, 3 and 4, certain subregions are subjected to progressively higher levels of water acquisitions (subregions 5, 8, 11, 12, and 13). These subregions would be more sensitive to slight differences in model data definition, resulting in the gradual increase in groundwater pumping revealed in Table 2a. The other subregions may have responded to the economic incentives discussed previously.

In summary:

- The small increase in groundwater pumping in Alternatives 2, 3, and 4 was not anticipated or intended, but we believe it to be a more realistic estimate of regional response to water acquisition. Given the inability of Interior to prevent groundwater pumping in non-acquisition areas, a strict analytical assumption preventing new pumping in all areas is untenable. If water acquisition could in fact increase groundwater pumping indirectly (i.e., in non-acquisition areas), then the PEIS should identify this as a potentially significant impact, and not simply assume that it cannot occur.

- Although the analysis appropriately identified indirect groundwater pumping increases as an impact, the size of the increases is small relative to total water use, and within the precision of the modeling effort.

- The rankings of alternatives based on economic or groundwater criteria will not be affected by the relatively small pumping increases.

TABLE 1

SUMMARY OF AVERAGE ANNUAL GROUNDWATER PUMPING FOR THE NO-ACTION ALTERNATIVE (in taf) (Avg. for 1922-90)

SUBREGION	MUNICIPAL & INDUSTRIAL	AGRICUL-TURAL	TOTAL
1	57	10	67
2	62	509	571
3	14	342	356
4	6	301	307
5	50	492	542
6	57	451	508
7	213	206	419
8	26	798	824
9	120	109	229
10	19	416	435
11	130	37	167
12	80	173	253
13	101	919	1020
14	8	722	730
15	43	1300	1343
16	277	62	339
17	74	416	490
18	135	1006	1141
19	8	359	367
20	31	298	329
21	179	536	715
Sacramento Region (subr. 1-9)	606	3217	3823
San Joaquin Region (subr. 10-13)	330	1545	1875
Tulare Region (subr. 14-21)	754	4700	5454
Total	1689	9463	11152

TABLE 2a

AVERAGE ANNUAL AGRICULTURAL GROUNDWATER PUMPING FOR EACH PEIS ALTERNATIVE (in taf) (Avg. for 1922-90)

SUBREGION	NO-ACTION ALT	ALT 1	ALT 2	ALT 3	ALT 4
1	10	10	10	10	10
2	509	514	515	517	517
3	342	358	352	343	346
4	301	309	313	317	317
5	492	509	515	530	531
6	451	461	462	463	464
7	206	207	207	207	207
8	798	808	810	841	841
9	109	109	108	102	103
10	416	473	474	480	474
11	37	36	39	47	48
12	173	175	181	187	187
13	919	900	905	912	911
14	722	829	831	749	832
15	1300	1287	1299	1293	1311
16	62	64	64	65	65
17	416	414	412	409	410
18	1006	1008	1012	1015	1015
19	359	344	347	328	352
20	298	301	302	302	303
21	536	522	522	498	527
Sacramento Region (subr. 1-9)	3217	3286	3292	3329	3336
San Joaquin Region (subr. 10-13)	1545	1584	1600	1626	1619
Tulare Region (subr. 14-21)	4700	4769	4789	4658	4815
Total	9463	9639	9681	9613	9770

TABLE 2b

DIFFERENCE IN AVERAGE ANNUAL AGRICULTURAL GROUNDWATER PUMPING FROM ALTERNATIVE 1 (in taf) (Avg. for 1922-90)

SUBREGION	ALT 2	ALT 3	ALT 4
1	0	0	0
2	1	3	4
3	-6	-15	-12
4	4	8	8
5	6	21	23
6	1	2	2
7	0	-1	-1
8	1	33	33
9	-1	-7	-6
10	1	7	1
11	3	11	12
12	6	12	11
13	5	12	11
14	1	-80	3
15	12	6	24
16	0	1	1
17	-2	-5	-5
18	4	7	7
19	3	-16	8
20	1	1	2
21	0	-24	5
Sacramento Region (subr. 1-9)	6	44	51
San Joaquin Region (subr. 10-13)	16	41	35
Tulare Region (subr. 14-21)	20	-111	45
Total	42	-26	131

Source: CVGSM water use budget output data.

ATTACHMENT B

TABLES AND FIGURES BY CVGSM SUBREGION

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Attachment B

TABLES AND FIGURES BY CVGSM SUBREGION

Attachment B is intended to supplement the groundwater analysis of the Central Valley regional aquifer system presented in Chapter III (Environmental Consequences). Additional details of the quantitative analysis are provided for the 21 subregions of the Central Valley Ground-Surface Water Model (CVGSM). Details regarding the description of CVGSM is provided under separate cover (see CVGSM Methodology and Modeling Technical Appendix). A list is provided below regarding the order, table number, and figure number of the supplemental information provided in this attachment.

TABLES B-1 THROUGH B-21:

- Average Annual Groundwater Budget for Alternatives 1 through 4 (by subregion)

TABLES B-22 THROUGH B-42:

- Average Annual Groundwater Budget for Supplemental Analyses 1a and 1d (by subregion)

FIGURES B-1 THROUGH B-63 (a):

- Simulated Pumping and Recharge for Alternatives 1 through 4 (by subregion)
- Cumulative Change in Groundwater Storage for Alternatives 1 through 4 (by subregion)
- Net Change in Groundwater Storage during the 69-Year Simulation Period for Alternatives 1 through 4 (by subregion)

FIGURES B-64 THROUGH B-126 (a):

- Simulated Pumping and Recharge for Supplemental Analyses 1a and 1d (by subregion)
- Cumulative Change in Groundwater Storage for Supplemental Analyses 1a and 1d (by subregion)
- Net Change in Groundwater Storage during the 69-Year Simulation Period for Supplemental Analyses 1a and 1d (by subregion)

TABLE B-1

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 1 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	Alternative (1)					Difference (Alternative Compared to No-Action Alternative) (1)			
	No-Action	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Recharge									
Deep Percolation (2)	173	173	173	173	173	0	0	0	0
Gain from Streams	-78	-77	-77	-77	-77	1	1	1	1
Recharge (3)	0	0	0	0	0	0	0	0	0
Boundary Inflows (4)	-28	-28	-28	-28	-28	0	0	0	0
Total Recharge	**67**	**68**	**68**	**68**	**68**	**1**	**1**	**1**	**1**
Discharge									
Groundwater Pumping	67	67	67	67	67	0	0	0	0
Total Discharge	**67**	**67**	**67**	**67**	**67**	**0**	**0**	**0**	**0**
Change in Groundwater Storage (5)	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B- 2

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 2 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	Alternative (1)					Difference (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	384	385	385	386	385	1	1	2	1
Gain from Streams	47	50	51	52	53	3	4	5	6
Recharge (3)	7	6	6	7	6	-1	-1	0	-1
Boundary Inflows (4)	125	124	125	124	124	-1	0	-1	-1
Total Recharge	**563**	**565**	**567**	**569**	**568**	**2**	**4**	**6**	**5**
Discharge									
Groundwater Pumping	571	575	576	578	578	4	5	7	7
Total Discharge	**571**	**575**	**576**	**578**	**578**	**4**	**5**	**7**	**7**
Change in Groundwater Storage (5)	**-8**	**-10**	**-9**	**-9**	**-10**	**-2**	**-1**	**-1**	**-2**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) *Change in groundwater storage is calculated from* Total Recharge minus Total Discharge.

TABLE B-3

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 3 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	Alternative (1)					Difference (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	441	453	461	460	460	12	20	19	19
Gain from Streams	-37	-36	-44	-48	-45	1	-7	-11	-8
Recharge (3)	11	11	11	11	11	0	0	0	0
Boundary Inflows (4)	-60	-60	-65	-69	-68	0	-5	-9	-8
Total Recharge	**355**	**368**	**363**	**354**	**358**	**13**	**8**	**-1**	**3**
Discharge									
Groundwater Pumping	356	371	365	356	359	15	9	0	3
Total Discharge	**356**	**371**	**365**	**356**	**359**	**15**	**9**	**0**	**3**
Change in Groundwater Storage (5)	**-1**	**-3**	**-2**	**-2**	**-1**	**-2**	**-1**	**-1**	**0**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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TABLE B-4

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 4 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	Alternative (1)					Difference (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	89	96	97	97	97	7	8	8	8
Gain from Streams	103	104	103	105	106	1	0	2	3
Recharge (3)	0	0	0	0	0	0	0	0	0
Boundary Inflows (4)	114	113	117	118	118	-1	3	4	4
Total Recharge	**306**	**313**	**317**	**320**	**321**	**7**	**11**	**14**	**15**
Discharge									
Groundwater Pumping	307	314	318	322	322	7	11	15	15
Total Discharge	**307**	**314**	**318**	**322**	**322**	**7**	**11**	**15**	**15**
Change in Groundwater Storage (5)	**-1**	**-1**	**-1**	**-2**	**-1**	**0**	**0**	**-1**	**0**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080510

TABLE B-5

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 5 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	Alternative (1)					Difference (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	564	573	575	558	559	9	11	-6	-5
Gain from Streams	-17	-10	-6	20	21	7	11	37	38
Recharge (3)	5	5	5	5	5	0	0	0	0
Boundary Inflows (4)	7	8	8	11	11	1	1	4	4
Total Recharge	**559**	**576**	**582**	**594**	**596**	**17**	**23**	**35**	**37**
Discharge									
Groundwater Pumping	558	575	582	597	598	17	24	39	40
Total Discharge	**558**	**575**	**582**	**597**	**598**	**17**	**24**	**39**	**40**
Change in Groundwater Storage (5)	**1**	**1**	**0**	**-3**	**-2**	**0**	**-1**	**-4**	**-3**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080514

TABLE B-6

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 6 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	202	205	205	205	205	3	3	3	3
Gain from Streams	204	207	207	207	207	3	3	3	3
Recharge (3)	15	15	15	15	15	0	0	0	0
Boundary Inflows (4)	72	76	77	77	77	4	5	5	5
Total Recharge	**493**	**503**	**504**	**504**	**504**	**10**	**11**	**11**	**11**
Discharge									
Groundwater Pumping	508	518	519	520	520	10	11	12	12
Total Discharge	**508**	**518**	**519**	**520**	**520**	**10**	**11**	**12**	**12**
Change in Groundwater Storage (5)	**-15**	**-15**	**-15**	**-16**	**-16**	**0**	**0**	**-1**	**-1**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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TABLE B-7

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 7 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	138	138	138	138	138	0	0	0	0
Gain from Streams	159	161	161	163	163	2	2	4	4
Recharge (3)	15	15	15	15	15	0	0	0	0
Boundary Inflows (4)	58	57	57	55	55	-1	-1	-3	-3
Total Recharge	**370**	**371**	**371**	**371**	**371**	**1**	**1**	**1**	**1**
Discharge									
Groundwater Pumping	403	406	406	405	406	3	3	2	3
Total Discharge	**403**	**406**	**406**	**405**	**406**	**3**	**3**	**2**	**3**
Change in Groundwater Storage (5)	**-33**	**-35**	**-35**	**-34**	**-35**	**-2**	**-2**	**-1**	**-2**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080513

TABLE B-8

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 8 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	117	117	117	115	115	0	0	-2	-2
Gain from Streams	373	377	377	410	410	4	4	37	37
Recharge (3)	4	4	4	4	4	0	0	0	0
Boundary Inflows (4)	301	307	307	307	307	6	6	6	6
Total Recharge	**795**	**805**	**805**	**836**	**836**	**10**	**10**	**41**	**41**
Discharge									
Groundwater Pumping	824	836	837	868	868	12	13	44	44
Total Discharge	**824**	**836**	**837**	**868**	**868**	**12**	**13**	**44**	**44**
Change in Groundwater Storage (5)	**-29**	**-31**	**-32**	**-32**	**-32**	**-2**	**-3**	**-3**	**-3**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-9

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 9 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Recharge									
Deep Percolation (2)	378	376	375	363	363	-2	-3	-15	-15
Gain from Streams	16	19	21	27	28	3	5	11	12
Recharge (3)	0	0	0	0	0	0	0	0	0
Boundary Inflows (4)	-143	-144	-147	-148	-147	-1	-4	-5	-4
Total Recharge	**251**	**251**	**249**	**242**	**244**	**0**	**-2**	**-9**	**-7**
Discharge									
Groundwater Pumping	229	230	228	223	224	1	-1	-6	-5
Total Discharge	**229**	**230**	**228**	**223**	**224**	**1**	**-1**	**-6**	**-5**
Change in Groundwater Storage (5)	**22**	**21**	**21**	**19**	**20**	**-1**	**-1**	**-3**	**-2**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-10

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 10 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Recharge									
Deep Percolation (2)	205	215	221	225	219	10	16	20	14
Gain from Streams	166	187	189	196	195	21	23	30	29
Recharge (3)	89	98	98	95	99	9	9	6	10
Boundary Inflows (4)	-19	-5	-10	-13	-16	14	9	6	3
Total Recharge	**441**	**495**	**498**	**503**	**497**	**54**	**57**	**62**	**56**
Discharge									
Groundwater Pumping	435	494	496	500	496	59	61	65	61
Total Discharge	**435**	**494**	**496**	**500**	**496**	**59**	**61**	**65**	**61**
Change in Groundwater Storage (5)	**6**	**1**	**2**	**3**	**1**	**-5**	**-4**	**-3**	**-5**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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TABLE B-11

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 11 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	480	479	461	404	404	-1	-19	-76	-76
Gain from Streams	-320	-313	-287	-204	-203	7	33	116	117
Recharge (3)	130	130	124	101	101	0	-6	-29	-29
Boundary Inflows (4)	-123	-129	-132	-131	-132	-6	-9	-8	-9
Total Recharge	**167**	**167**	**166**	**170**	**170**	**0**	**-1**	**3**	**3**
Discharge									
Groundwater Pumping	167	166	167	172	173	-1	0	5	6
Total Discharge	**167**	**166**	**167**	**172**	**173**	**-1**	**0**	**5**	**6**
Change in Groundwater Storage (5)	**0**	**1**	**-1**	**-2**	**-3**	**1**	**-1**	**-2**	**-3**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080517

TABLE B-12

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 12 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	132	132	130	124	124	0	-2	-8	-8
Gain from Streams	39	40	63	85	86	1	24	46	47
Recharge (3)	87	87	80	68	68	0	-7	-19	-19
Boundary Inflows (4)	-9	-9	-17	-16	-17	0	-8	-7	-8
Total Recharge	**249**	**250**	**256**	**261**	**261**	**1**	**7**	**12**	**12**
Discharge									
Groundwater Pumping	253	255	260	265	265	2	7	12	12
Total Discharge	**253**	**255**	**260**	**265**	**265**	**2**	**7**	**12**	**12**
Change in Groundwater Storage (5)	**-4**	**-5**	**-4**	**-4**	**-4**	**-1**	**0**	**0**	**0**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080521

TABLE B-13

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 13 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	260	259	259	253	252	-1	-1	-7	-8
Gain from Streams	428	422	422	413	416	-6	-6	-15	-12
Recharge (3)	127	132	116	104	104	5	-11	-23	-23
Boundary Inflows (4)	176	158	177	210	202	-18	1	34	26
Total Recharge	**991**	**971**	**974**	**980**	**974**	**-20**	**-17**	**-11**	**-17**
Discharge									
Groundwater Pumping	1,020	1,000	1,005	1,012	1,011	-20	-15	-8	-9
Total Discharge	**1,020**	**1,000**	**1,005**	**1,012**	**1,011**	**-20**	**-15**	**-8**	**-9**
Change in Groundwater Storage (5)	**-29**	**-29**	**-31**	**-32**	**-37**	**0**	**-2**	**-3**	**-8**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080519

TABLE B-14

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 14 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	472	431	432	446	425	-41	-40	-26	-47
Gain from Streams	0	0	0	0	0	0	0	0	0
Recharge (3)	25	25	25	25	25	0	0	0	0
Boundary Inflows (4)	176	293	293	218	297	117	117	42	121
Total Recharge	**673**	**749**	**750**	**689**	**747**	**76**	**77**	**16**	**74**
Discharge									
Groundwater Pumping	730	839	840	757	842	109	110	27	112
Total Discharge	**730**	**839**	**840**	**757**	**842**	**109**	**110**	**27**	**112**
Change in Groundwater Storage (5)	**-57**	**-90**	**-90**	**-68**	**-95**	**-33**	**-33**	**-11**	**-38**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

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C-080523

TABLE B-15

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 15 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compared to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	226	226	227	228	228	0	1	2	2
Gain from Streams	179	187	189	179	192	8	10	0	13
Recharge (3)	78	99	100	88	102	21	22	10	24
Boundary Inflows (4)	769	708	714	744	714	-61	-55	-25	-55
Total Recharge	**1,252**	**1,220**	**1,230**	**1,239**	**1,236**	**-32**	**-22**	**-13**	**-16**
Discharge									
Groundwater Pumping	1,355	1,340	1,353	1,346	1,366	-15	-2	-9	11
Total Discharge	**1,355**	**1,340**	**1,353**	**1,346**	**1,366**	**-15**	**-2**	**-9**	**11**
Change in Groundwater Storage (5)	**-103**	**-120**	**-123**	**-107**	**-130**	**-17**	**-20**	**-4**	**-27**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080521

TABLE B-16

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 16 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	46	45	45	45	45	-1	-1	-1	-1
Gain from Streams	0	0	0	0	0	0	0	0	0
Recharge (3)	50	50	50	50	50	0	0	0	0
Boundary Inflows (4)	196	190	190	193	189	-6	-6	-3	-7
Total Recharge	**292**	**285**	**285**	**288**	**284**	**-7**	**-7**	**-4**	**-8**
Discharge									
Groundwater Pumping	327	322	322	323	323	-5	-5	-4	-4
Total Discharge	**327**	**322**	**322**	**323**	**323**	**-5**	**-5**	**-4**	**-4**
Change in Groundwater Storage (5)	**-35**	**-37**	**-37**	**-35**	**-39**	**-2**	**-2**	**0**	**-4**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080525

TABLE B-17

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 17 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	185	185	184	184	184	0	-1	-1	-1
Gain from Streams	162	162	162	161	162	0	0	-1	0
Recharge (3)	102	102	102	102	102	0	0	0	0
Boundary Inflows (4)	17	14	12	13	9	-3	-5	-4	-8
Total Recharge	**466**	**463**	**460**	**460**	**457**	**-3**	**-6**	**-6**	**-9**
Discharge									
Groundwater Pumping	490	487	484	481	482	-3	-6	-9	-8
Total Discharge	**490**	**487**	**484**	**481**	**482**	**-3**	**-6**	**-9**	**-8**
Change in Groundwater Storage (5)	**-24**	**-24**	**-24**	**-21**	**-25**	**0**	**0**	**3**	**-1**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080523

C-080526

TABLE B-18

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 18 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	768	768	769	770	770	0	1	2	2
Gain from Streams	158	158	159	158	160	0	1	0	2
Recharge (3)	141	142	142	141	142	1	1	0	1
Boundary Inflows (4)	50	50	49	57	49	0	-1	7	-1
Total Recharge	**1,117**	**1,118**	**1,119**	**1,126**	**1,121**	**1**	**2**	**9**	**4**
Discharge									
Groundwater Pumping	1,141	1,142	1,146	1,149	1,149	1	5	8	8
Total Discharge	**1,141**	**1,142**	**1,146**	**1,149**	**1,149**	**1**	**5**	**8**	**8**
Change in Groundwater Storage (5)	**-24**	**-24**	**-27**	**-23**	**-28**	**0**	**-3**	**1**	**-4**

NOTES:

(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C—080524

C-080527

TABLE B-19

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 19 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	336	347	343	346	340	11	7	10	4
Gain from Streams	0	0	0	0	0	0	0	0	0
Recharge (3)	5	5	5	5	5	0	0	0	0
Boundary Inflows (4)	89	71	76	62	80	-18	-13	-27	-9
Total Recharge	**430**	**423**	**424**	**413**	**425**	**-7**	**-6**	**-17**	**-5**
Discharge									
Groundwater Pumping	367	351	354	334	358	-16	-13	-33	-9
Total Discharge	**367**	**351**	**354**	**334**	**358**	**-16**	**-13**	**-33**	**-9**
Change in Groundwater Storage (5)	**63**	**72**	**70**	**79**	**67**	**9**	**7**	**16**	**4**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080525

C-080528

TABLE B-20

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 20 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	170	170	170	171	170	0	0	1	0
Gain from Streams	0	0	0	0	0	0	0	0	0
Recharge (3)	11	12	12	12	12	1	1	1	1
Boundary Inflows (4)	159	164	164	166	163	5	5	7	4
Total Recharge	**340**	**346**	**346**	**349**	**345**	**6**	**6**	**9**	**5**
Discharge									
Groundwater Pumping	329	331	332	332	333	2	3	3	4
Total Discharge	**329**	**331**	**332**	**332**	**333**	**2**	**3**	**3**	**4**
Change in Groundwater Storage (5)	**11**	**15**	**14**	**17**	**12**	**4**	**3**	**6**	**1**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-21

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 21 (1922-1990) FOR ALTERNATIVES 1 THROUGH 4

	ALTERNATIVE (1)					DIFFERENCE (Alternative Compare to No-Action Alternative) (1)			
	No-Action	1	2	3	4	1	2	3	4
Recharge									
Deep Percolation (2)	451	448	461	462	458	-3	10	11	7
Gain from Streams	225	216	212	195	217	-9	-13	-30	-8
Recharge (3)	108	103	102	96	104	-5	-6	-12	-4
Boundary Inflows (4)	-26	-22	-26	-24	-27	4	0	2	-1
Total Recharge	**758**	**745**	**749**	**729**	**752**	**-13**	**-9**	**-29**	**-6**
Discharge									
Groundwater Pumping	715	698	698	671	703	-17	-17	-44	-12
Total Discharge	**715**	**698**	**698**	**671**	**703**	**-17**	**-17**	**-44**	**-12**
Change in Groundwater Storage (5)	**43**	**47**	**51**	**58**	**49**	**4**	**8**	**15**	**6**

NOTES:
(1) All values in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-22

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 1 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	173	173	173	173	0	0	0
Gain from Streams	-78	-77	-77	-77	1	1	1
Recharge (3)	0	0	0	0	0	0	0
Boundary Inflows (4)	-28	-28	-28	-28	0	0	0
Total Recharge	**67**	**68**	**68**	**68**	**1**	**1**	**1**
Discharge							
Groundwater Pumping	67	67	67	67	0	0	0
Total Discharge	**67**	**67**	**67**	**67**	**0**	**0**	**0**
Change in Groundwater Storage (5)	**0**	**1**	**1**	**1**	**1**	**1**	**1**

NOTES:

(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-23

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 2 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	384	385	385	385	1	1	1
Gain from Streams	47	50	50	51	3	3	4
Recharge (3)	7	6	6	6	-1	-1	-1
Boundary Inflows (4)	125	124	124	124	-1	-1	-1
Total Recharge	**563**	**565**	**565**	**566**	**2**	**2**	**3**
Discharge							
Groundwater Pumping	571	575	575	576	4	4	5
Total Discharge	**571**	**575**	**575**	**576**	**4**	**4**	**5**
Change in Groundwater Storage (5)	**-8**	**-10**	**-10**	**-10**	**-2**	**-2**	**-2**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080532

TABLE B-24

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 3 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	441	453	452	456	12	11	15
Gain from Streams	-37	-36	-36	-35	1	1	2
Recharge (3)	11	11	11	11	0	0	0
Boundary Inflows (4)	-60	-60	-59	-58	0	1	2
Total Recharge	**355**	**368**	**368**	**374**	**13**	**13**	**19**
Discharge							
Groundwater Pumping	356	371	371	377	15	15	21
Total Discharge	**356**	**371**	**371**	**377**	**15**	**15**	**21**
Change in Groundwater Storage (5)	**-1**	**-3**	**-3**	**-3**	**-2**	**-2**	**-2**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080530

TABLE B-25

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 4 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	89	96	96	96	7	7	7
Gain from Streams	103	104	104	104	1	1	1
Recharge (3)	0	0	0	0	0	0	0
Boundary Inflows (4)	114	113	113	113	-1	-1	-1
Total Recharge	**306**	**313**	**313**	**313**	**7**	**7**	**7**
Discharge							
Groundwater Pumping	307	314	314	314	7	7	7
Total Discharge	**307**	**314**	**314**	**314**	**7**	**7**	**7**
Change in Groundwater Storage (5)	**-1**	**-1**	**-1**	**-1**	**0**	**0**	**0**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080534

TABLE B-26

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 5 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	564	573	573	573	9	9	9
Gain from Streams	-17	-10	-10	-10	7	7	7
Recharge (3)	5	5	5	5	0	0	0
Boundary Inflows (4)	7	8	8	8	1	1	1
Total Recharge	**559**	**576**	**576**	**576**	**17**	**17**	**17**
Discharge							
Groundwater Pumping	558	575	575	575	17	17	17
Total Discharge	**558**	**575**	**575**	**575**	**17**	**17**	**17**
Change in Groundwater Storage (5)	**1**	**1**	**1**	**1**	**0**	**0**	**0**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C—080532

TABLE B-27

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 6 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	202	205	205	205	3	3	3
Gain from Streams	204	207	207	207	3	3	3
Recharge (3)	15	15	15	15	0	0	0
Boundary Inflows (4)	72	76	76	76	4	4	4
Total Recharge	**493**	**503**	**503**	**503**	**10**	**10**	**10**
Discharge							
Groundwater Pumping	508	518	518	518	10	10	10
Total Discharge	**508**	**518**	**518**	**518**	**10**	**10**	**10**
Change in Groundwater Storage (5)	**-15**	**-15**	**-15**	**-15**	**0**	**0**	**0**

NOTES:

(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-28

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 7 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	138	138	138	138	0	0	0
Gain from Streams	159	161	161	161	2	2	2
Recharge (3)	15	15	15	15	0	0	0
Boundary Inflows (4)	58	57	57	57	-1	-1	-1
Total Recharge	**370**	**371**	**371**	**371**	**1**	**1**	**1**
Discharge							
Groundwater Pumping	403	406	406	405	3	3	2
Total Discharge	**403**	**406**	**406**	**405**	**3**	**3**	**2**
Change in Groundwater Storage (5)	**-33**	**-35**	**-35**	**-34**	**-2**	**-2**	**-1**

NOTES:

(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-29

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 8 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	117	117	117	117	0	0	0
Gain from Streams	373	377	377	377	4	4	4
Recharge (3)	4	4	4	4	0	0	0
Boundary Inflows (4)	301	307	307	307	6	6	6
Total Recharge	**795**	**805**	**805**	**805**	**10**	**10**	**10**
Discharge							
Groundwater Pumping	824	836	836	836	12	12	12
Total Discharge	**824**	**836**	**836**	**836**	**12**	**12**	**12**
Change in Groundwater Storage (5)	**-29**	**-31**	**-31**	**-31**	**-2**	**-2**	**-2**

NOTES:

(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080538

TABLE B-30

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 9 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	378	376	376	376	-2	-2	-2
Gain from Streams	16	19	19	19	3	3	3
Recharge (3)	0	0	0	0	0	0	0
Boundary Inflows (4)	-143	-144	-145	-145	-1	-2	-2
Total Recharge	**251**	**251**	**250**	**250**	**0**	**-1**	**-1**
Discharge							
Groundwater Pumping	229	230	230	230	1	1	1
Total Discharge	**229**	**230**	**230**	**230**	**1**	**1**	**1**
Change in Groundwater Storage (5)	**22**	**21**	**20**	**20**	**-1**	**-2**	**-2**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080536

TABLE B-31

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 10 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	205	215	213	220	10	8	15
Gain from Streams	166	187	197	196	21	31	30
Recharge (3)	89	98	101	99	9	12	10
Boundary Inflows (4)	-19	-5	4	1	14	23	20
Total Recharge	**441**	**495**	**515**	**516**	**54**	**74**	**75**
Discharge							
Groundwater Pumping	435	494	515	515	59	80	80
Total Discharge	**435**	**494**	**515**	**515**	**59**	**80**	**80**
Change in Groundwater Storage (5)	**6**	**1**	**0**	**1**	**-5**	**-6**	**-5**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080540

TABLE B-32

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 11 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	480	479	479	479	-1	-1	-1
Gain from Streams	-320	-313	-311	-313	7	9	7
Recharge (3)	130	130	130	130	0	0	0
Boundary Inflows (4)	-123	-129	-132	-130	-6	-9	-7
Total Recharge	**167**	**167**	**166**	**166**	**0**	**-1**	**-1**
Discharge							
Groundwater Pumping	167	166	166	166	-1	-1	-1
Total Discharge	**167**	**166**	**166**	**166**	**-1**	**-1**	**-1**
Change in Groundwater Storage (5)	**0**	**1**	**0**	**0**	**1**	**0**	**0**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080538

TABLE B-33

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 12 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	132	132	133	132	0	1	0
Gain from Streams	39	40	41	41	1	2	2
Recharge (3)	87	87	87	87	0	0	0
Boundary Inflows (4)	-9	-9	-10	-10	0	-1	-1
Total Recharge	**249**	**250**	**251**	**250**	**1**	**2**	**1**
Discharge							
Groundwater Pumping	253	255	255	254	2	2	1
Total Discharge	**253**	**255**	**255**	**254**	**2**	**2**	**1**
Change in Groundwater Storage (5)	**-4**	**-5**	**-4**	**-4**	**-1**	**0**	**0**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-34

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 13 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	260	259	259	260	-1	-1	0
Gain from Streams	428	422	424	422	-6	-4	-6
Recharge (3	127	132	131	132	5	4	5
Boundary Inflows (4)	176	158	153	158	-18	-23	-18
Total Recharge	**991**	**971**	**967**	**972**	**-20**	**-24**	**-19**
Discharge							
Groundwater Pumping	1,020	1,000	1,000	1,002	-20	-20	-18
Total Discharge	**1,020**	**1,000**	**1,000**	**1,002**	**-20**	**-20**	**-18**
Change in Groundwater Storage (5)	**-29**	**-29**	**-33**	**-30**	**0**	**-4**	**-1**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080543

TABLE B-35

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 14 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	472	431	420	430	-41	-52	-42
Gain from Streams	0	0	0	0	0	0	0
Recharge (3)	25	25	25	25	0	0	0
Boundary Inflows (4)	176	293	336	296	117	160	120
Total Recharge	**673**	**749**	**781**	**751**	**76**	**108**	**78**
Discharge							
Groundwater Pumping	730	839	884	842	109	154	112
Total Discharge	**730**	**839**	**884**	**842**	**109**	**154**	**112**
Change in Groundwater Storage (5)	**-57**	**-90**	**-103**	**-91**	**-33**	**-46**	**-34**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080541

TABLE B-36

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 15 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	226	226	226	226	0	0	0
Gain from Streams	179	187	193	188	8	14	9
Recharge (3)	78	99	105	100	21	27	22
Boundary Inflows (4)	769	708	689	707	-61	-80	-62
Total Recharge	**1,252**	**1,220**	**1,213**	**1,221**	**-32**	**-39**	**-31**
Discharge							
Groundwater Pumping	1,355	1,340	1,343	1,340	-15	-12	-15
Total Discharge	**1,355**	**1,340**	**1,343**	**1,340**	**-15**	**-12**	**-15**
Change in Groundwater Storage (5)	**-103**	**-120**	**-130**	**-119**	**-17**	**-27**	**-16**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080545

TABLE B-37

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 16 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	46	45	45	45	-1	-1	-1
Gain from Streams	0	0	0	0	0	0	0
Recharge (3)	50	50	50	50	0	0	0
Boundary Inflows (4)	196	190	188	190	-6	-8	-6
Total Recharge	**292**	**285**	**283**	**285**	**-7**	**-9**	**-7**
Discharge							
Groundwater Pumping	327	322	322	322	-5	-5	-5
Total Discharge	**327**	**322**	**322**	**322**	**-5**	**-5**	**-5**
Change in Groundwater Storage (5)	**-35**	**-37**	**-39**	**-37**	**-2**	**-4**	**-2**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080543

TABLE B-38

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 17 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	185	185	185	185	0	0	0
Gain from Streams	162	162	162	162	0	0	0
Recharge (3)	102	102	102	102	0	0	0
Boundary Inflows (4)	17	14	13	15	-3	-4	-2
Total Recharge	**466**	**463**	**462**	**464**	**-3**	**-4**	**-2**
Discharge							
Groundwater Pumping	490	487	487	487	-3	-3	-3
Total Discharge	**490**	**487**	**487**	**487**	**-3**	**-3**	**-3**
Change in Groundwater Storage (5)	**-24**	**-24**	**-25**	**-23**	**0**	**-1**	**1**

NOTES:

(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.

(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.

(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.

(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.

(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-39

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 18 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative minus No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	768	768	768	768	0	0	0
Gain from Streams	158	158	159	158	0	1	0
Recharge (3)	141	142	142	142	1	1	1
Boundary Inflows (4)	50	50	47	49	0	-3	-1
Total Recharge	**1,117**	**1,118**	**1,116**	**1,117**	**1**	**-1**	**0**
Discharge							
Groundwater Pumping	1,141	1,142	1,142	1,142	1	1	1
Total Discharge	**1,141**	**1,142**	**1,142**	**1,142**	**1**	**1**	**1**
Change in Groundwater Storage (5)	**-24**	**-24**	**-26**	**-25**	**0**	**-2**	**-1**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

TABLE B-40

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 19 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	336	347	346	347	11	10	11
Gain from Streams	0	0	0	0	0	0	0
Recharge (3)	5	5	5	5	0	0	0
Boundary Inflows (4)	89	71	75	71	-18	-14	-18
Total Recharge	**430**	**423**	**426**	**423**	**-7**	**-4**	**-7**
Discharge							
Groundwater Pumping	367	351	356	351	-16	-11	-16
Total Discharge	**367**	**351**	**356**	**351**	**-16**	**-11**	**-16**
Change in Groundwater Storage (5)	**63**	**72**	**70**	**72**	**9**	**7**	**9**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C-080549

TABLE B-41

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 20 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE (Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	170	170	170	170	0	0	0
Gain from Streams	0	0	0	0	0	0	0
Recharge (3)	11	12	11	12	1	0	1
Boundary Inflows (4)	159	164	164	164	5	5	5
Total Recharge	**340**	**346**	**345**	**346**	**6**	**5**	**6**
Discharge							
Groundwater Pumping	329	331	332	331	2	3	2
Total Discharge	**329**	**331**	**332**	**331**	**2**	**3**	**2**
Change in Groundwater Storage (5)	**11**	**15**	**13**	**15**	**4**	**2**	**4**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

C—080547

TABLE B-42

AVERAGE ANNUAL GROUNDWATER BUDGET FOR SUBREGION 21 (1922-1990) FOR SUPPLEMENTAL ANALYSES 1a AND 1d

	ALTERNATIVE (1)				DIFFERENCE Alternative Compare to No-Action Alternative) (1)		
			Supplemental Analysis			Supplemental Analysis	
	No-Action Alternative	Alternative 1	1a	1d	Alternative 1	1a	1d
Recharge							
Deep Percolation (2)	451	448	446	447	-3	-5	-4
Gain from Streams	225	216	222	216	-9	-3	-9
Recharge (3)	108	103	105	103	-5	-3	-5
Boundary Inflows (4)	-26	-22	-23	-22	4	3	4
Total Recharge	**758**	**745**	**750**	**744**	**-13**	**-8**	**-14**
Discharge							
Groundwater Pumping	715	698	705	698	-17	-10	-17
Total Discharge	**715**	**698**	**705**	**698**	**-17**	**-10**	**-17**
Change in Groundwater Storage (5)	**43**	**47**	**45**	**46**	**4**	**2**	**3**

NOTES:
(1) All values presented in 1,000 acre-feet. For the purposes of presenting model results, data presented here have been rounded to the nearest 1,000 acre-feet. This may introduce small rounding error into the reported values.
(2) Amount of water percolating through the unsaturated zone and entering the aquifer resulting from rainfall and applied water.
(3) Recharge includes seepage from canals, artificial recharge, and seepage through lakes.
(4) Boundary inflow includes subsurface inflow at the exterior model boundary and from interior adjacent subregion boundaries.
(5) Change in groundwater storage is calculated from Total Recharge minus Total Discharge.

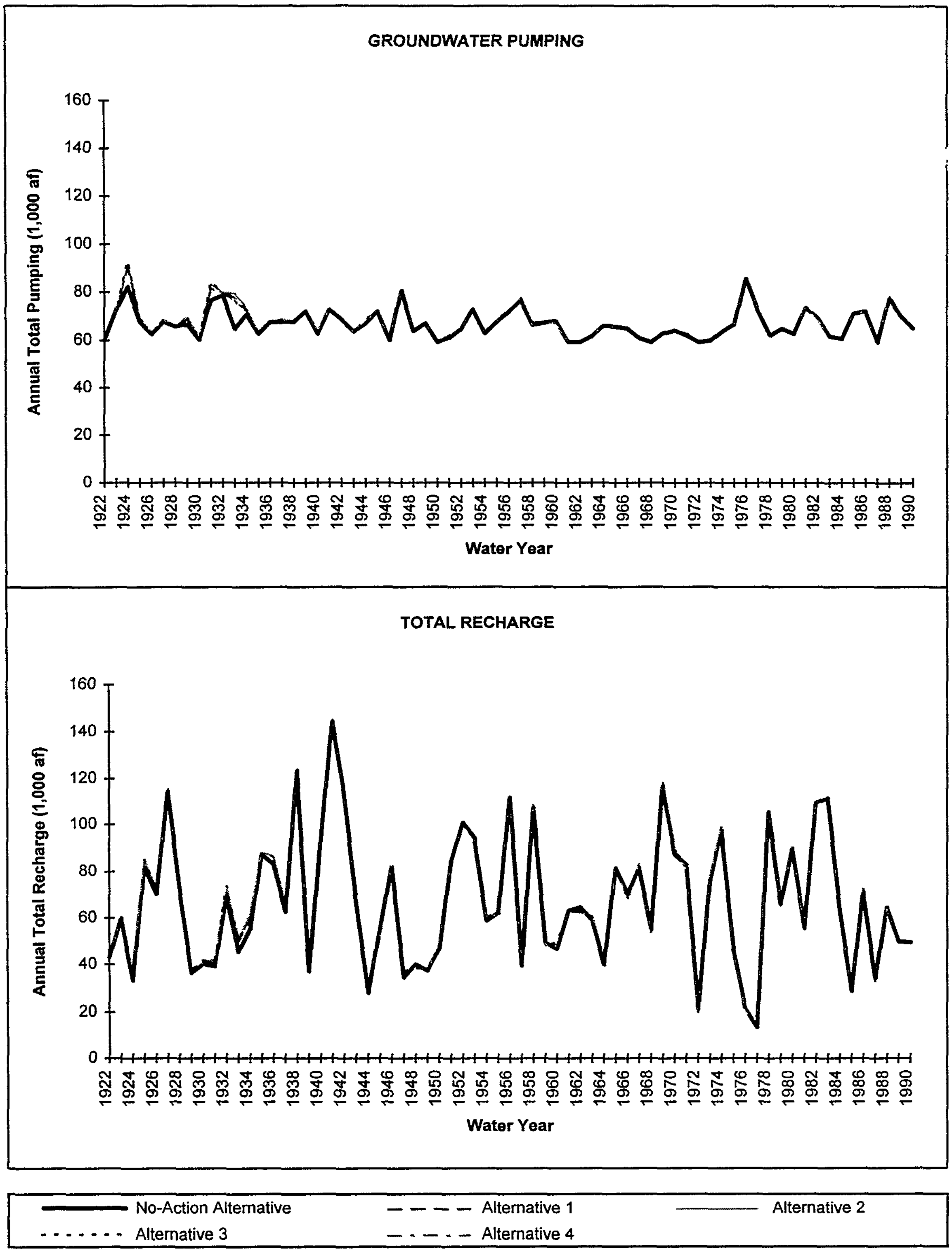

FIGURE B - 1
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 1

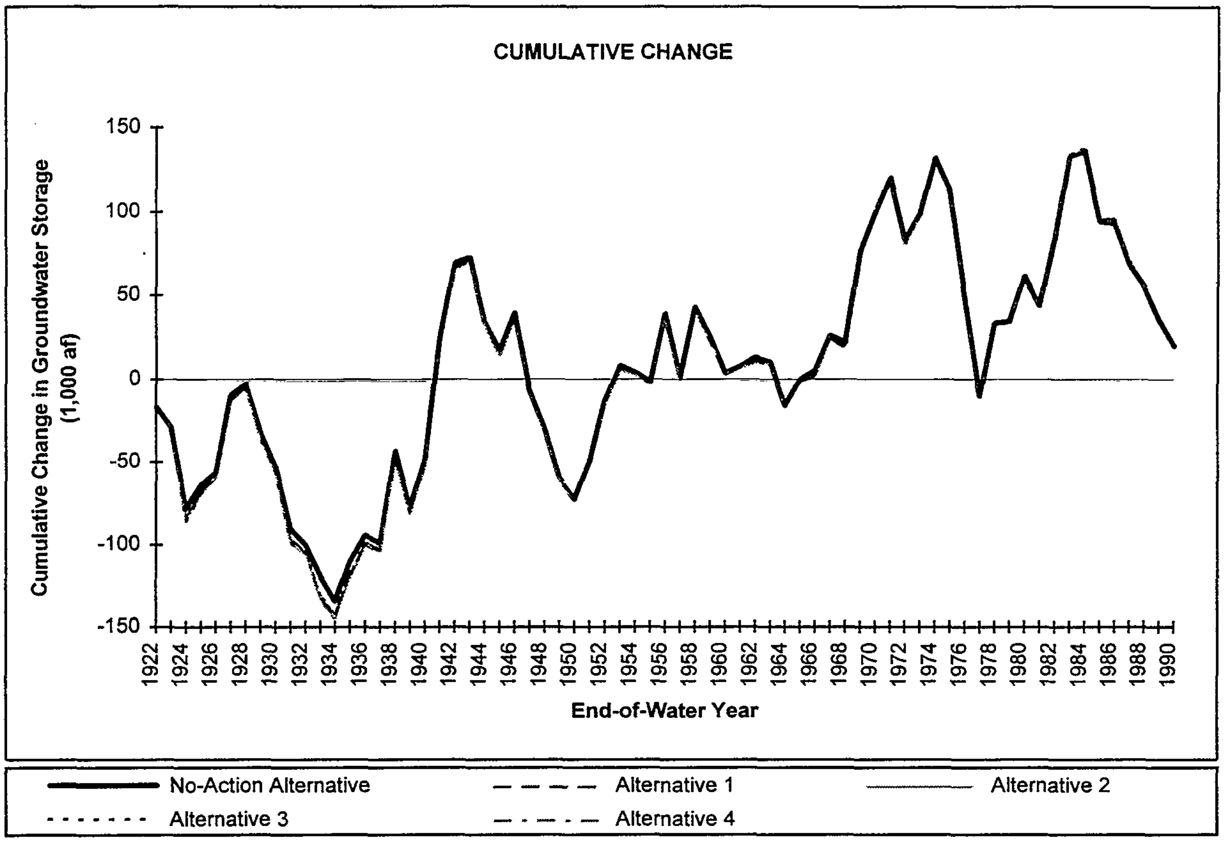

FIGURE B - 2
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 1

C—080550

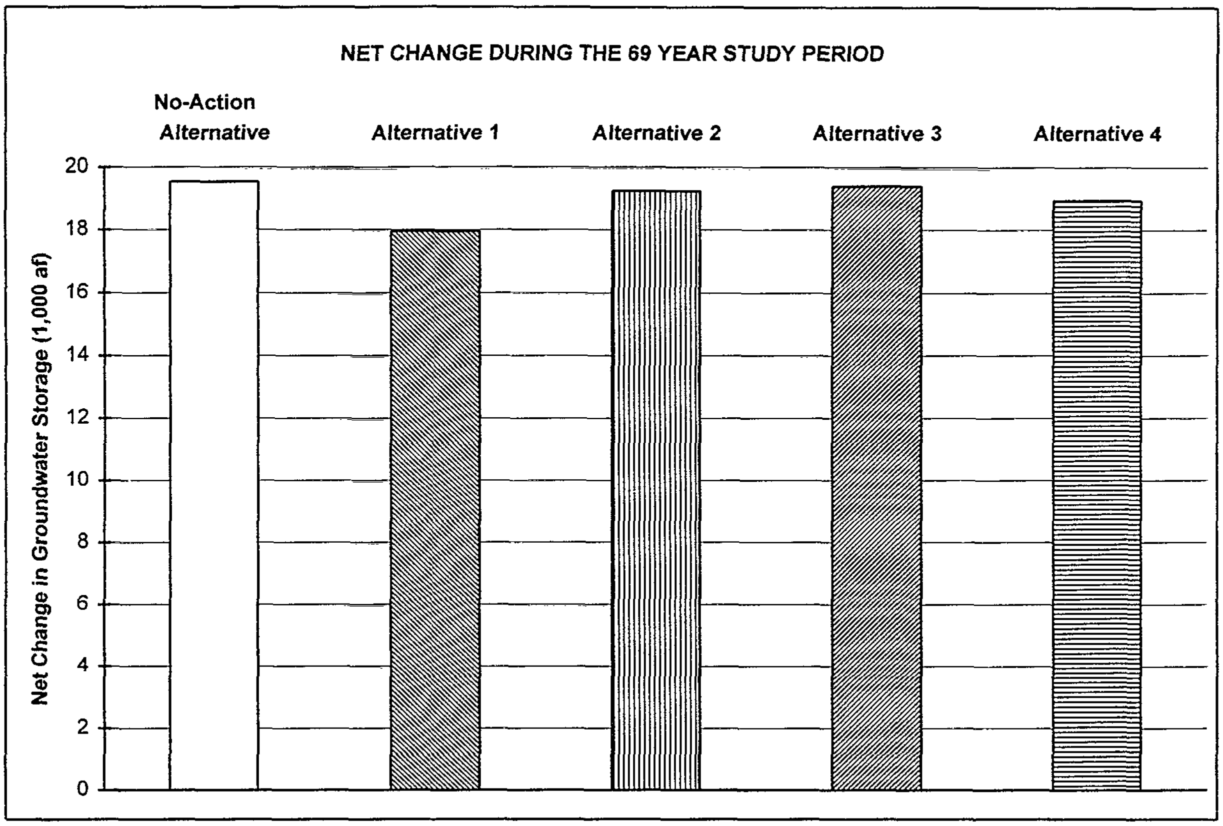

FIGURE B - 3
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 1

C —0 8 0 5 5 1

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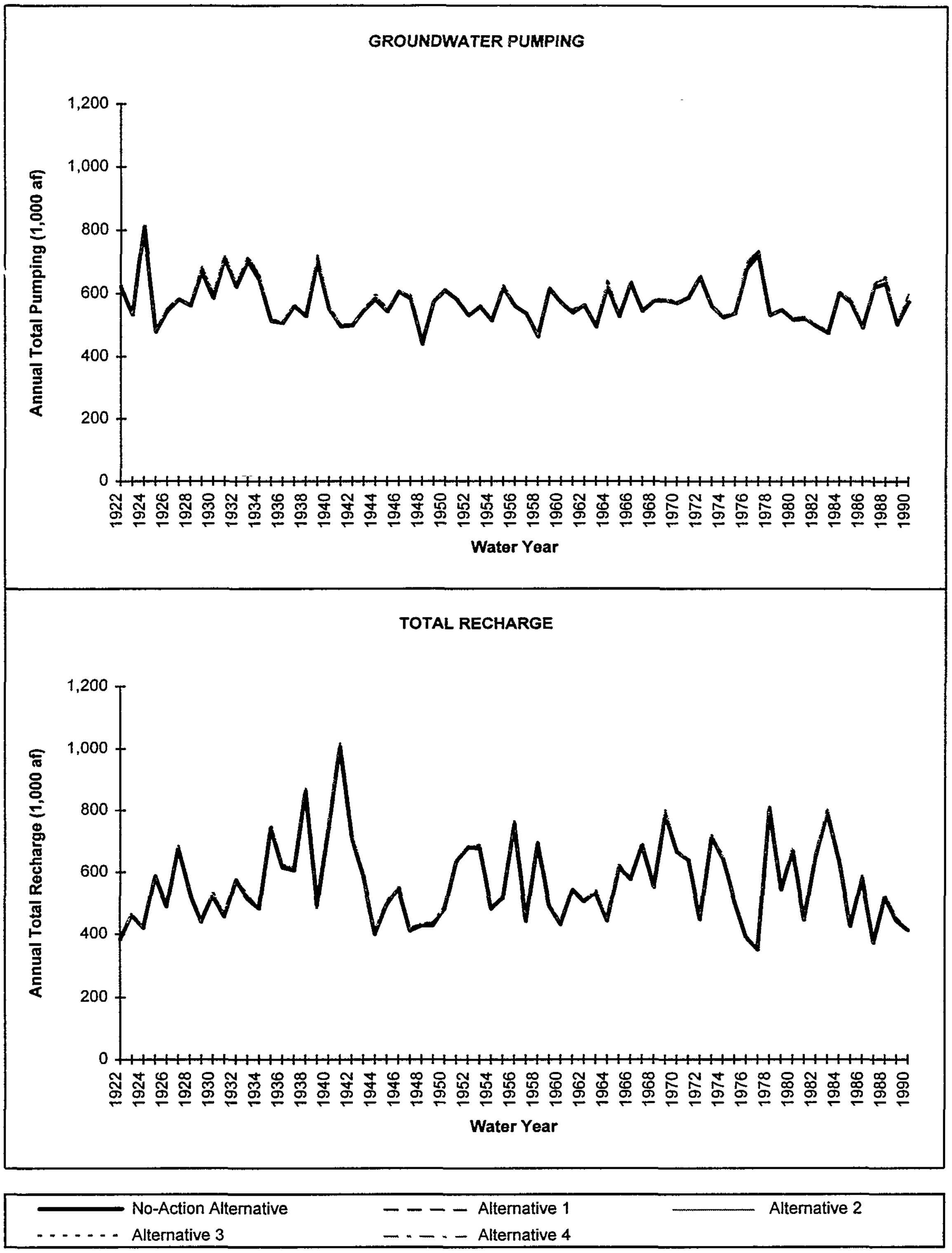

FIGURE B - 4
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 2

C—080553

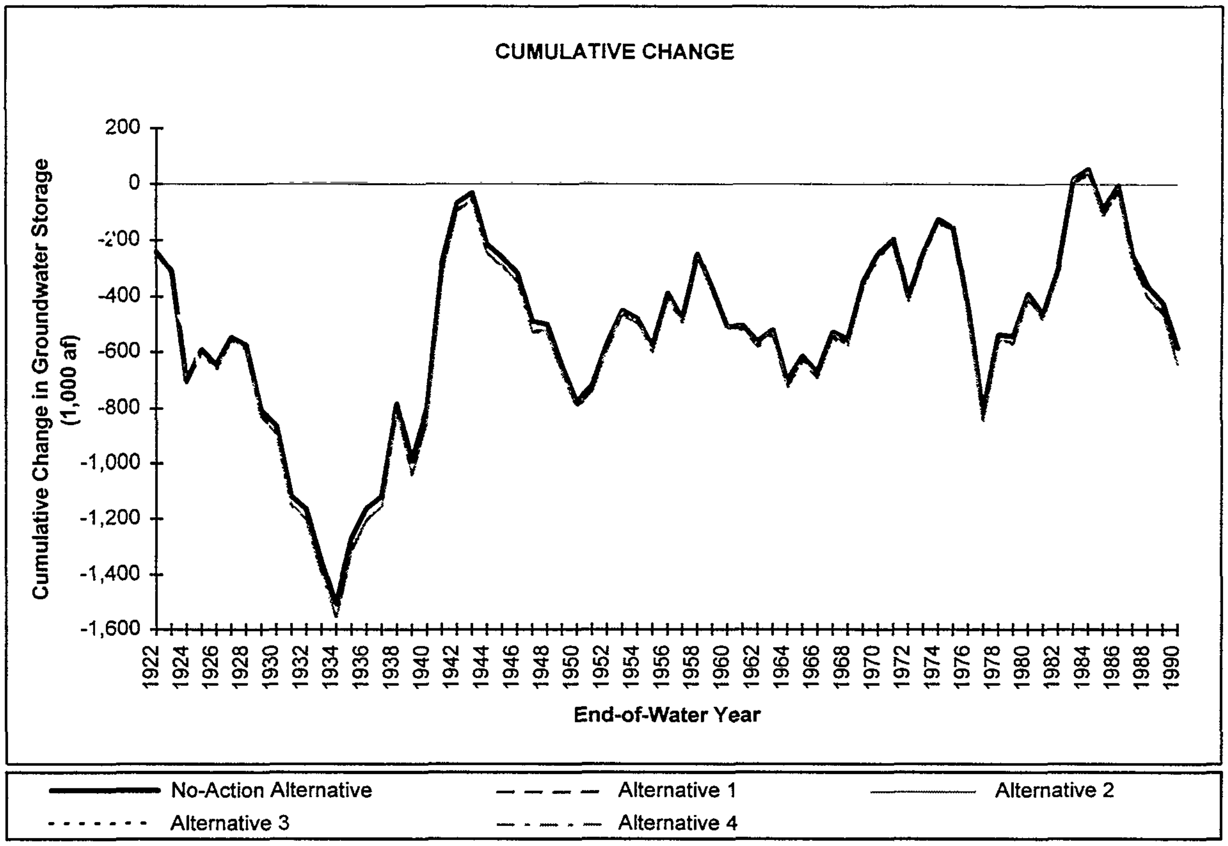

FIGURE B - 5
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 2

C—080554

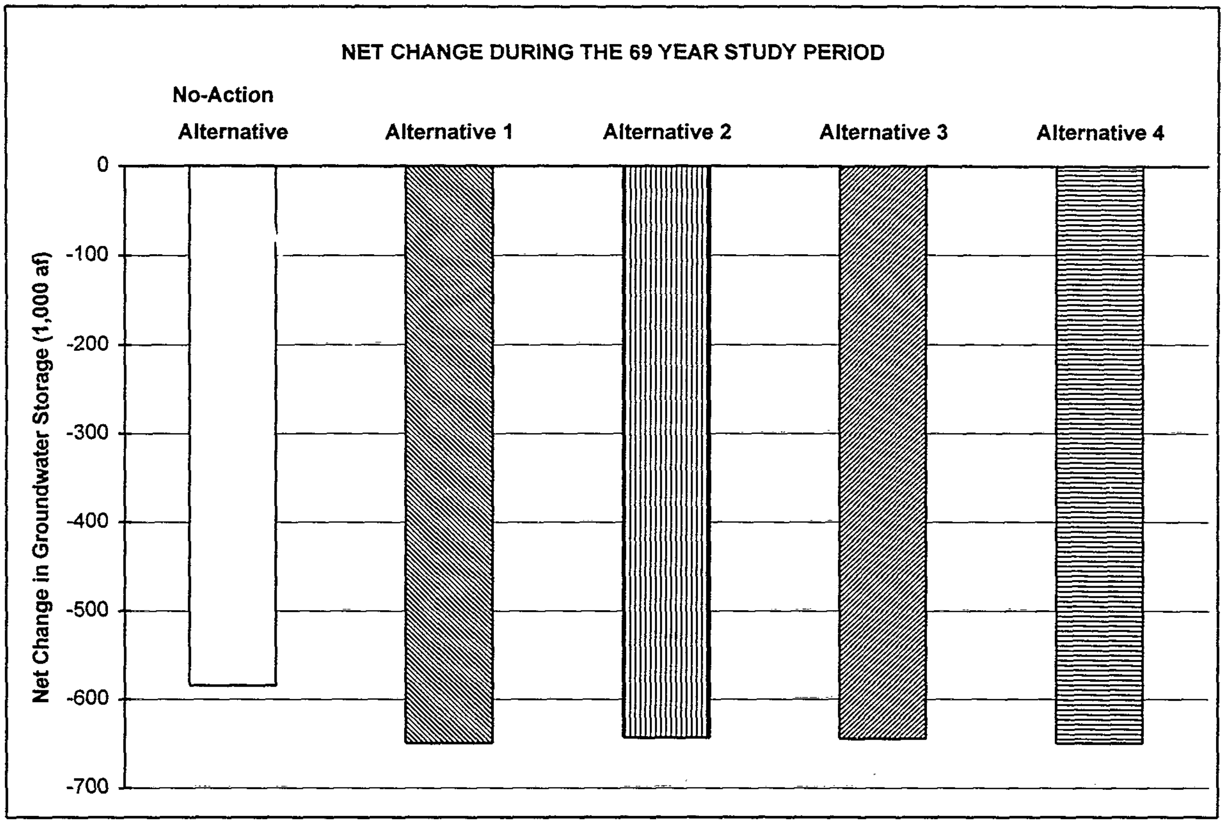

FIGURE B - 6
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 2

C—080555

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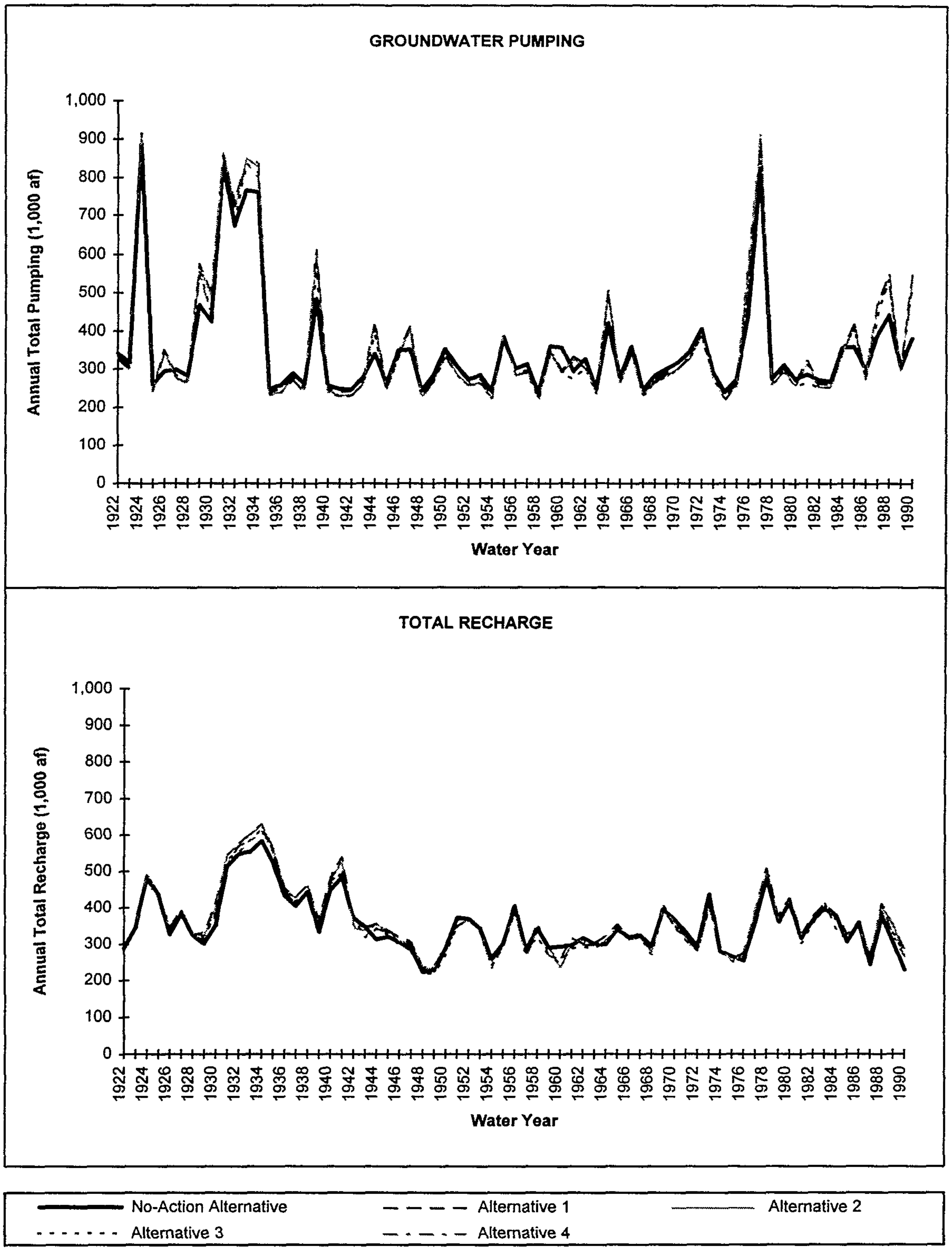

FIGURE B - 7
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 3

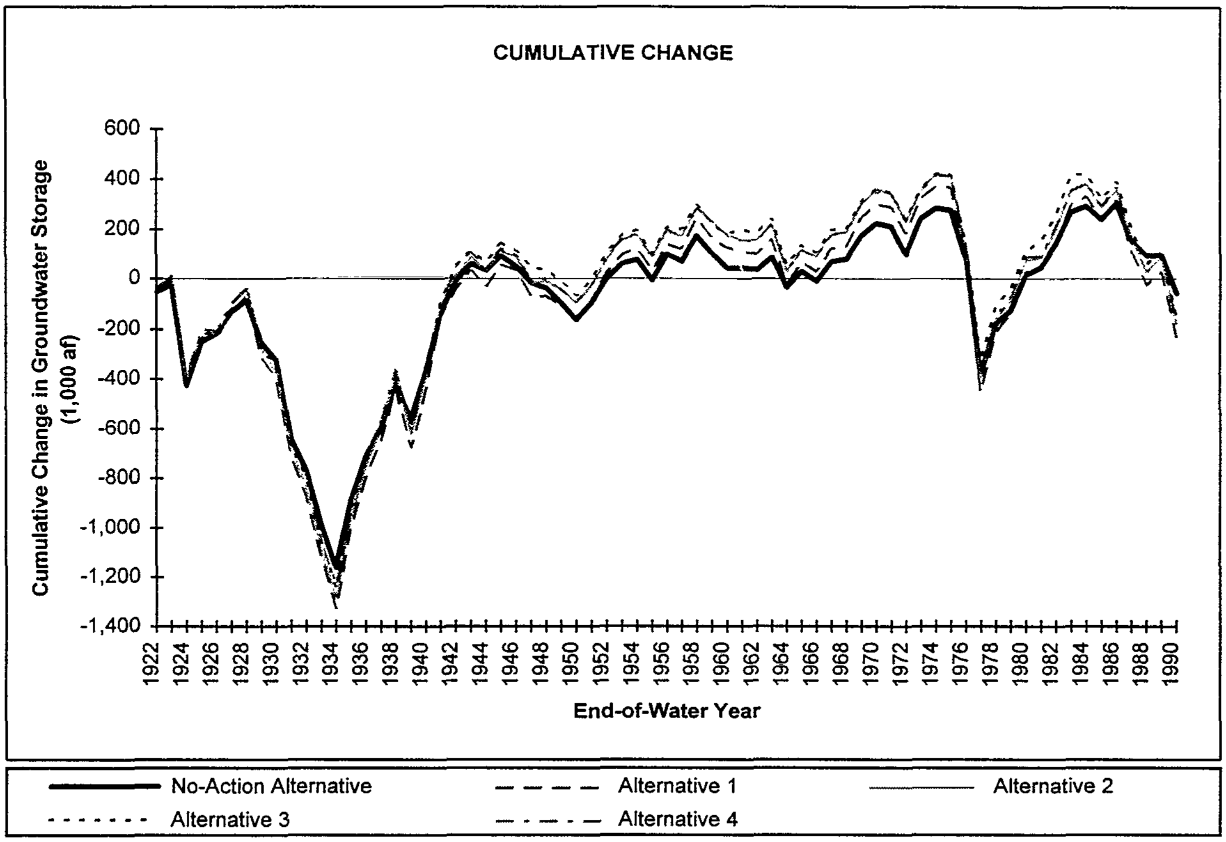

FIGURE B - 8
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 3

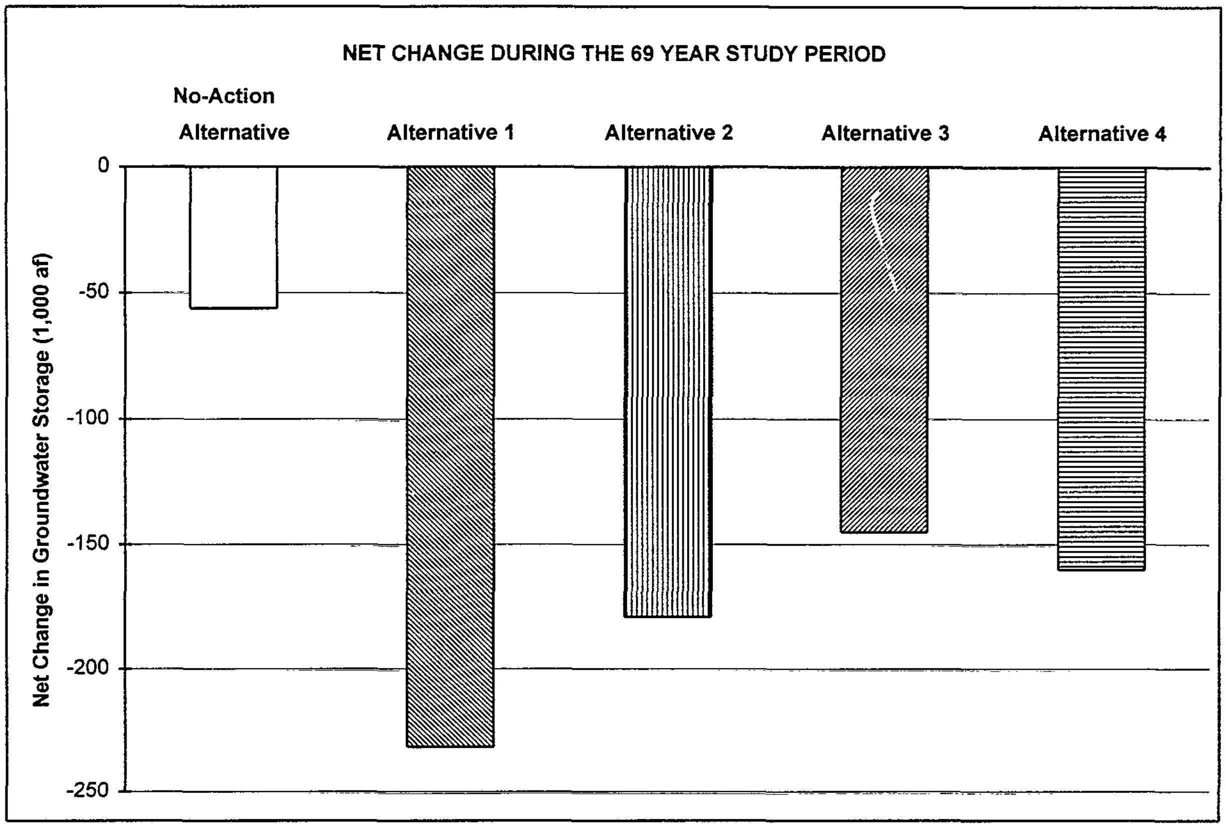

FIGURE B - 9
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 3

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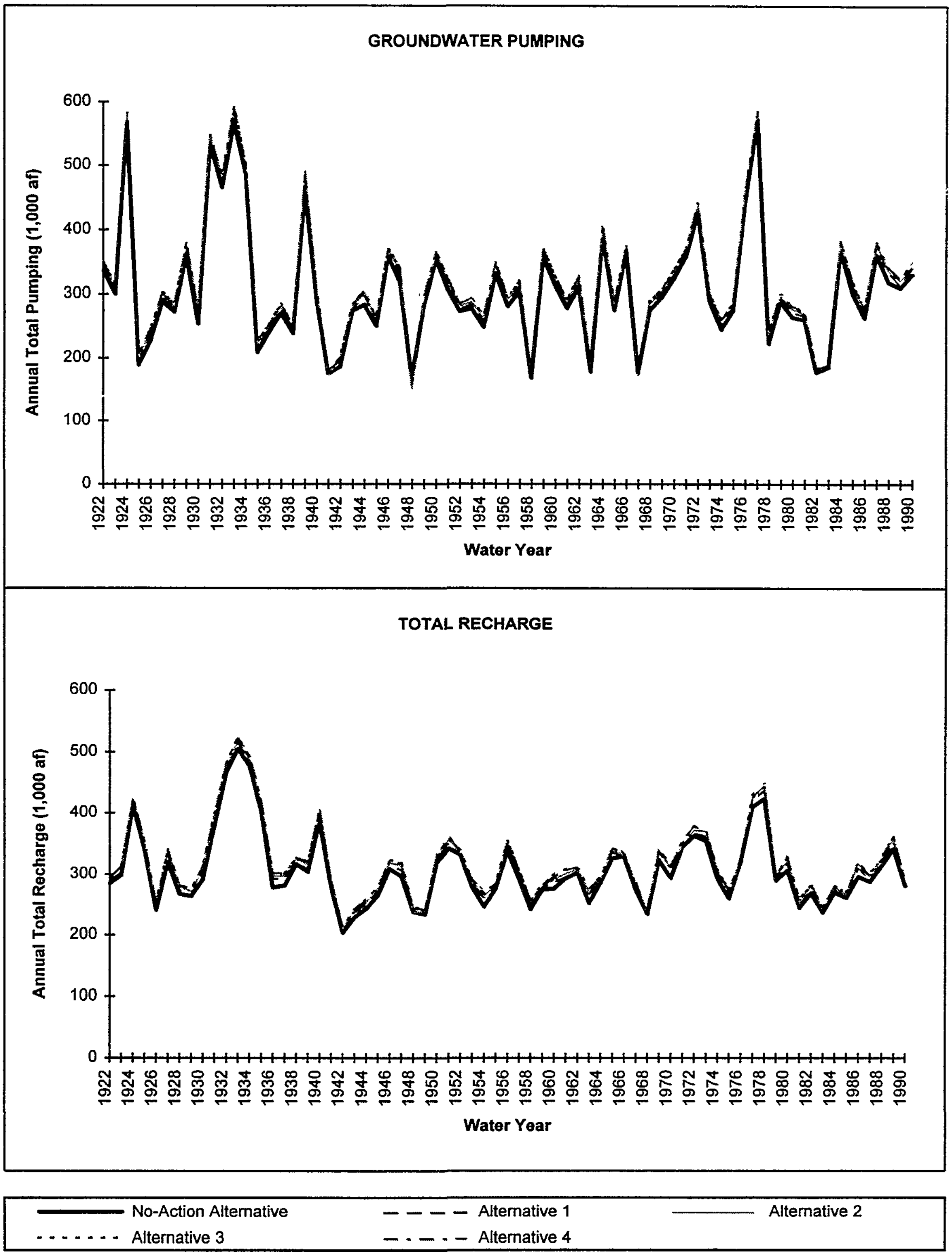

FIGURE B - 10
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 4

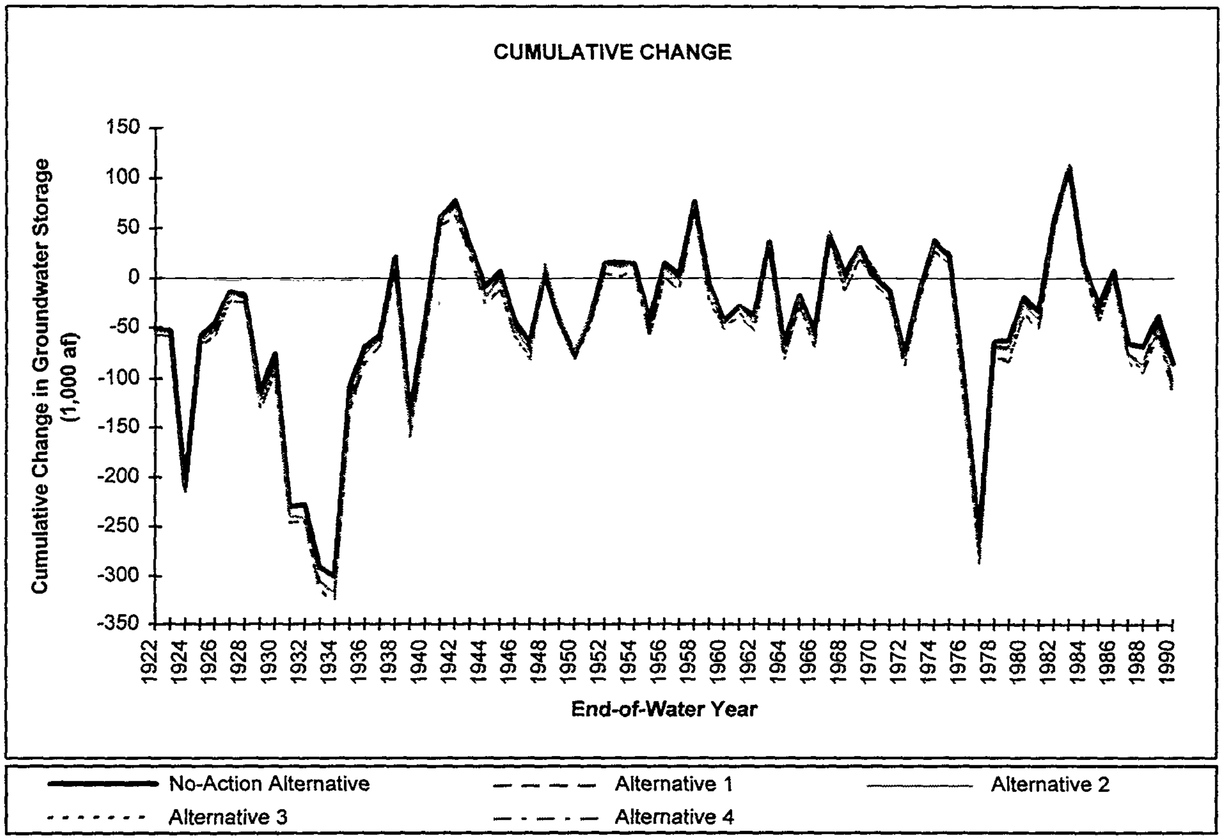

FIGURE B - 11
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 4

C-080562

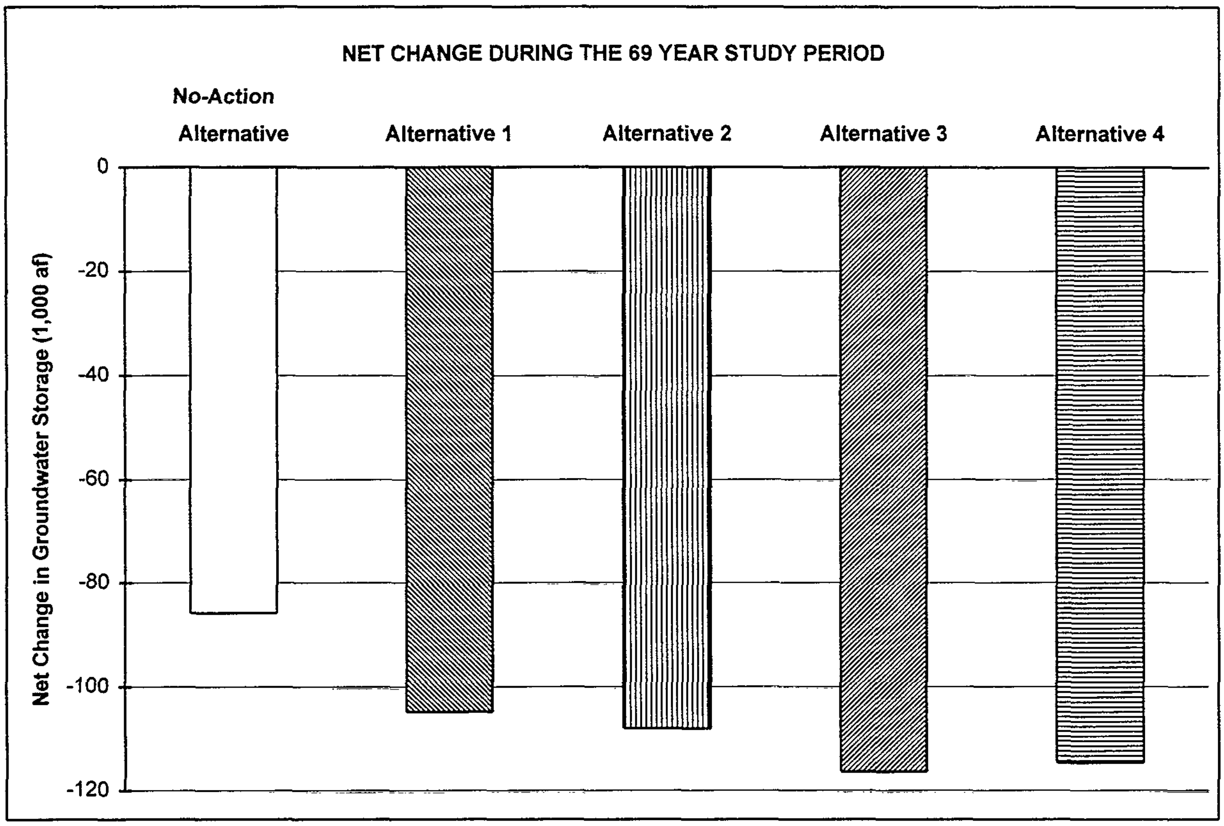

FIGURE B - 12
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 4

C —0 8 0 5 6 3

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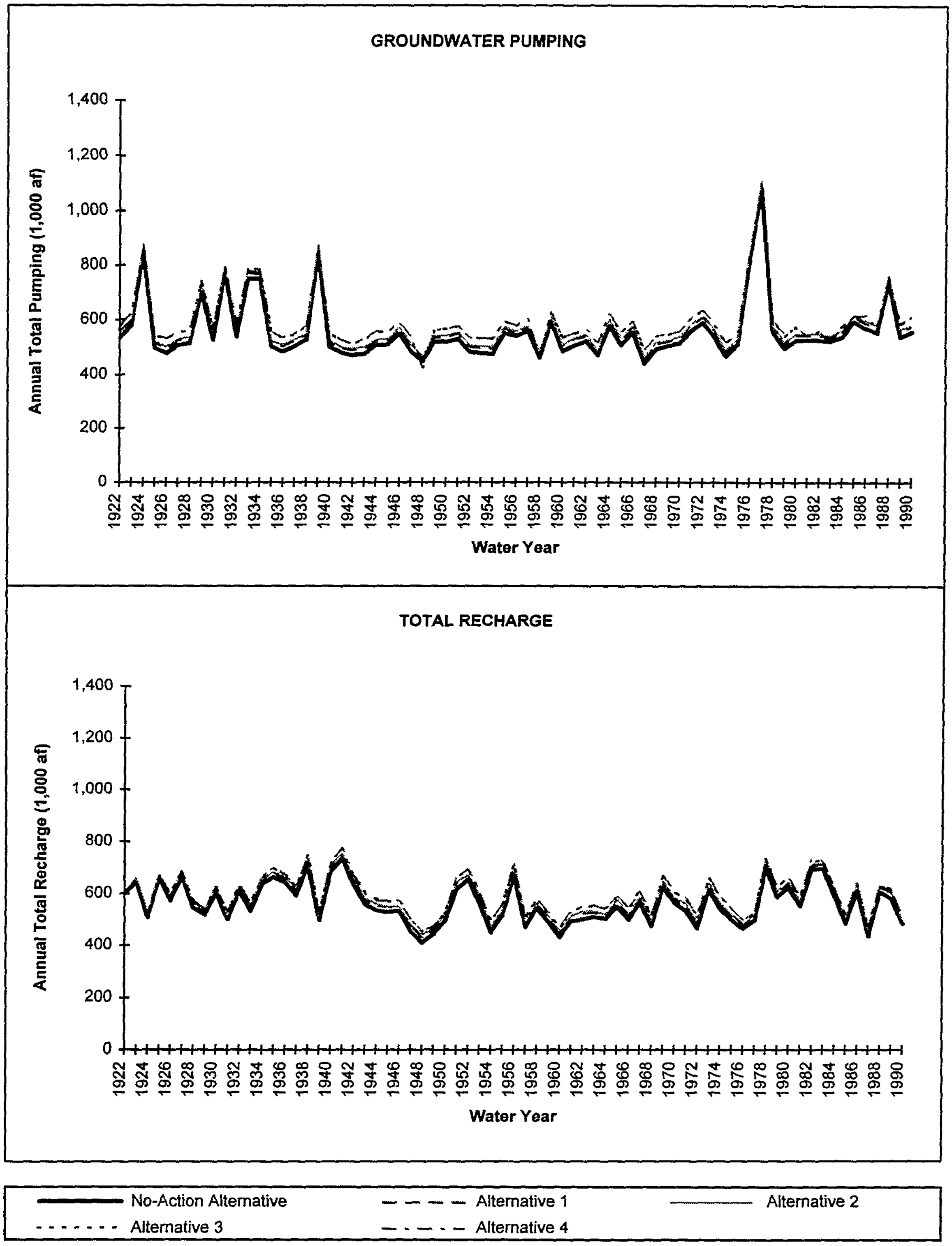

FIGURE B - 13
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 5

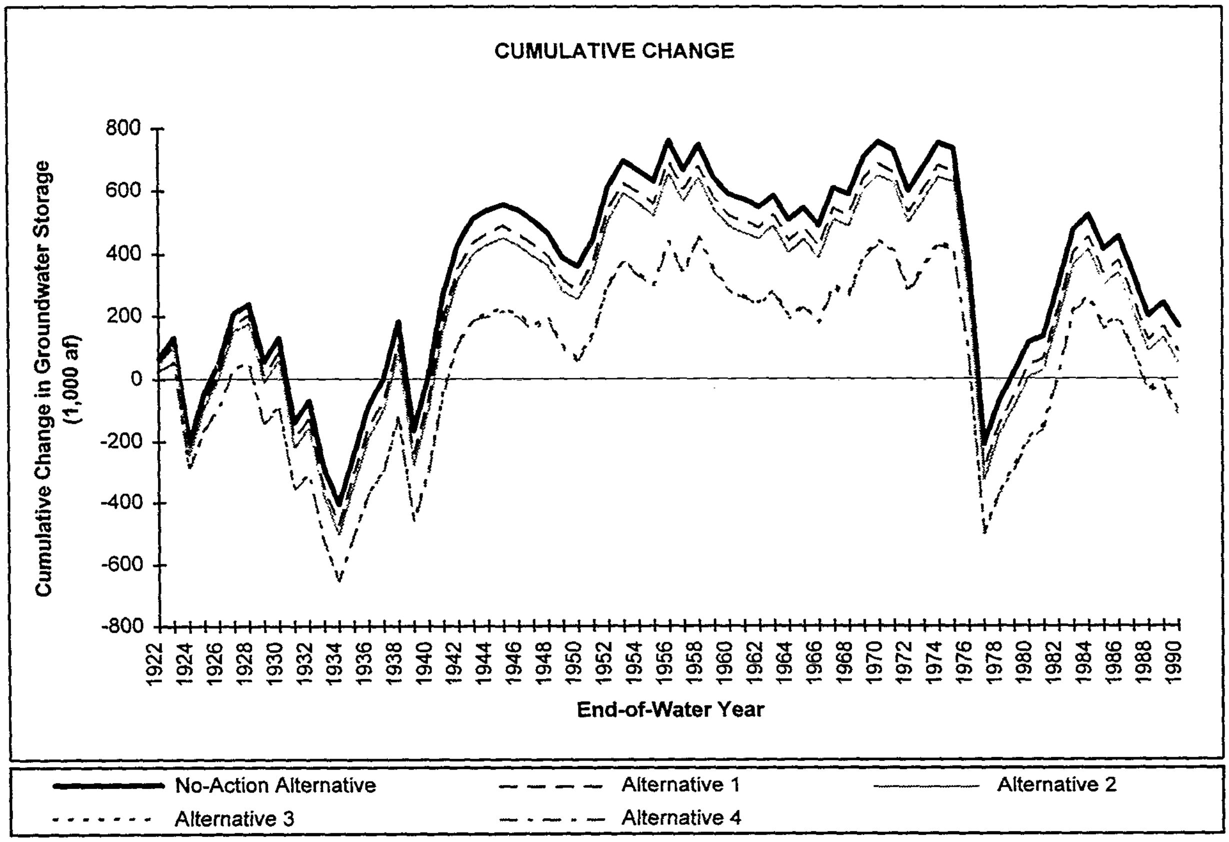

FIGURE B - 14
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 5

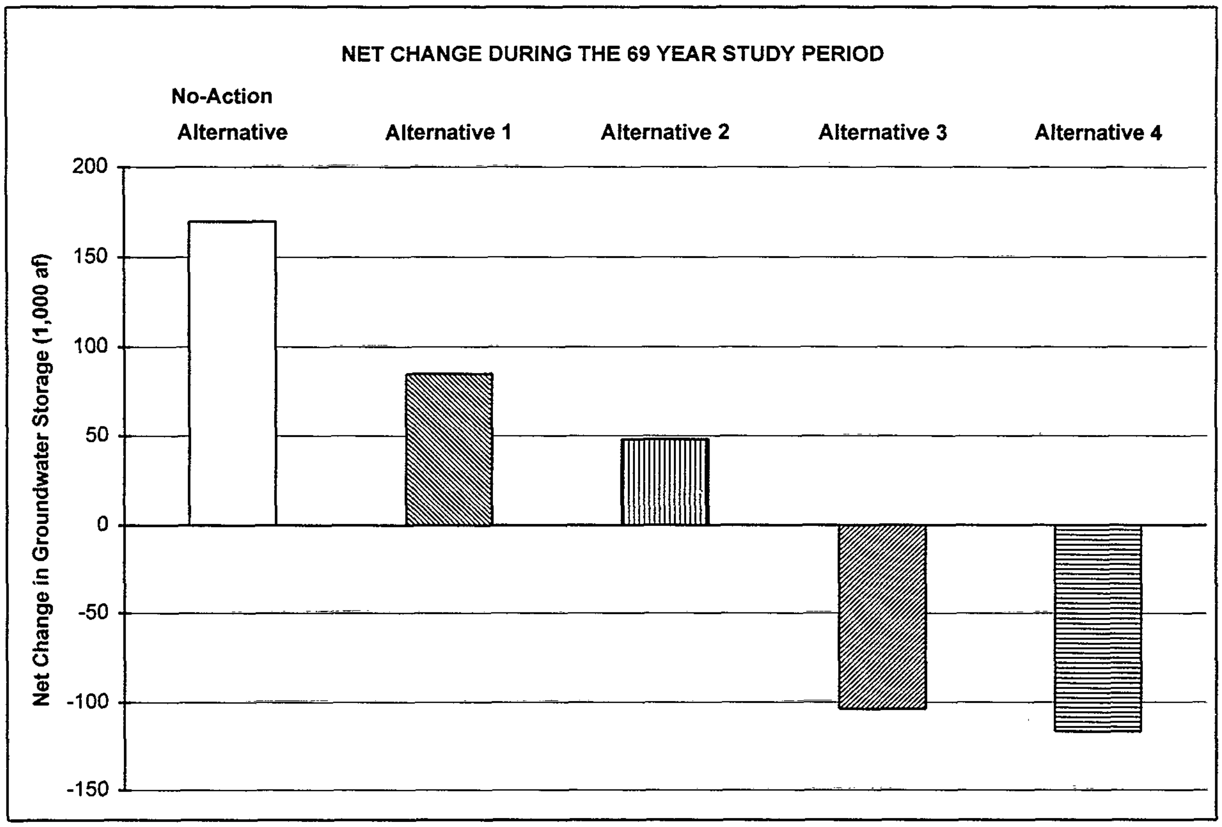

FIGURE B - 15
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 5

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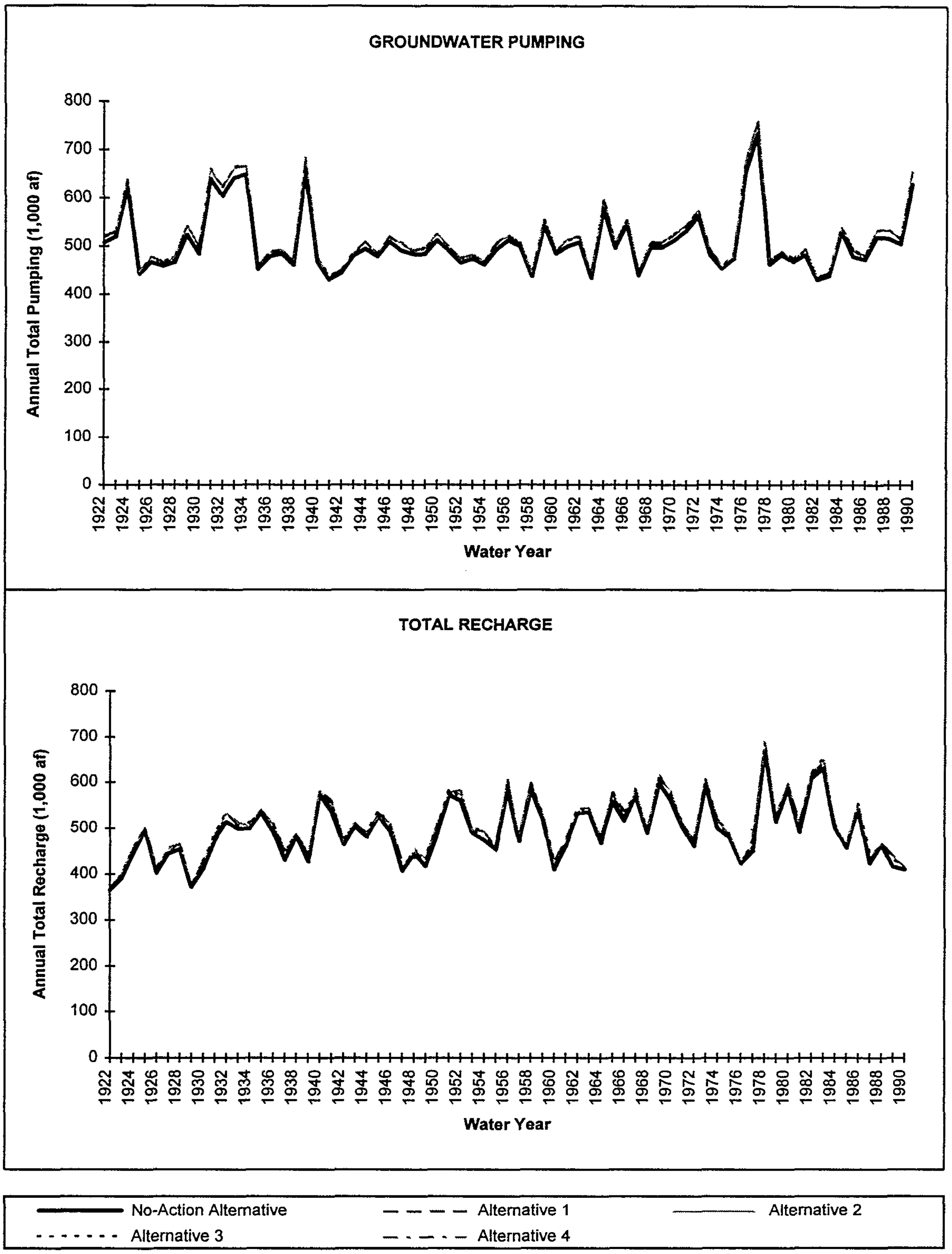

FIGURE B - 16
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 6

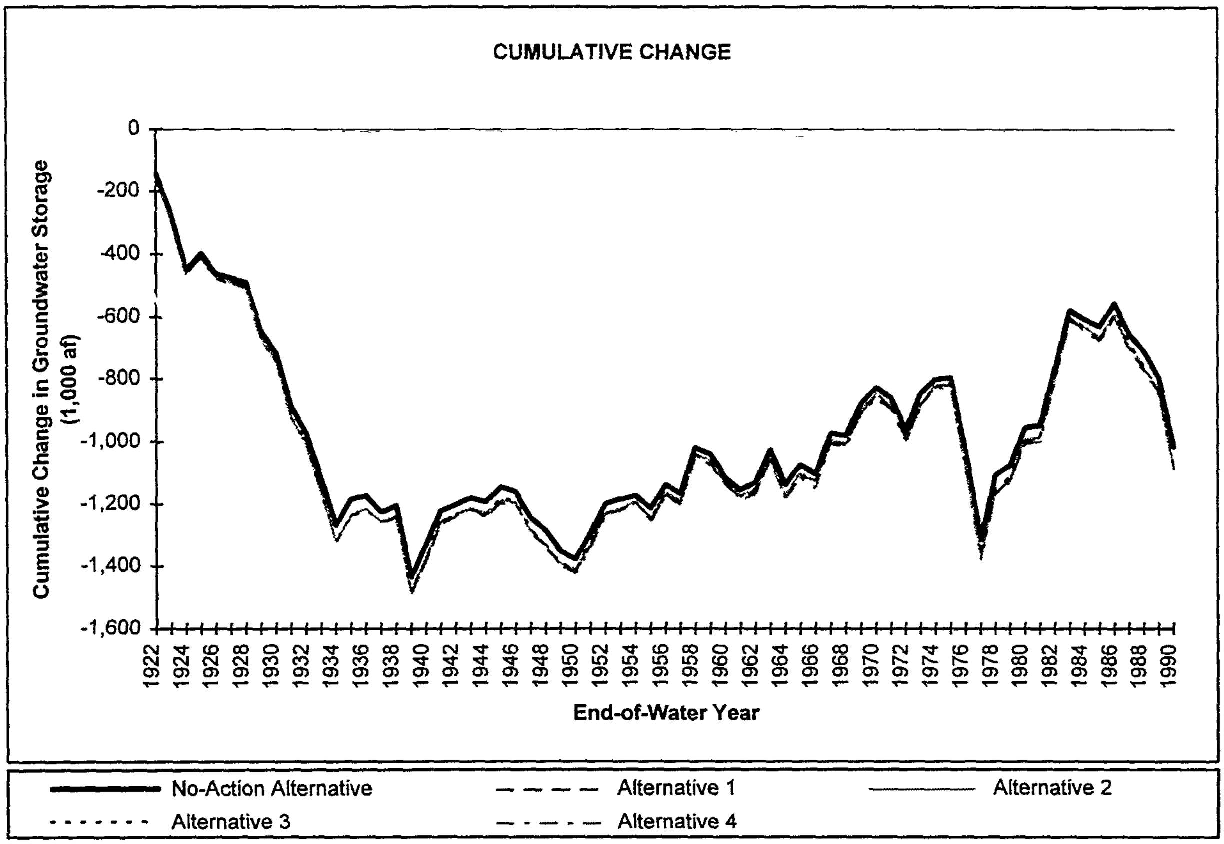

FIGURE B - 17
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 6

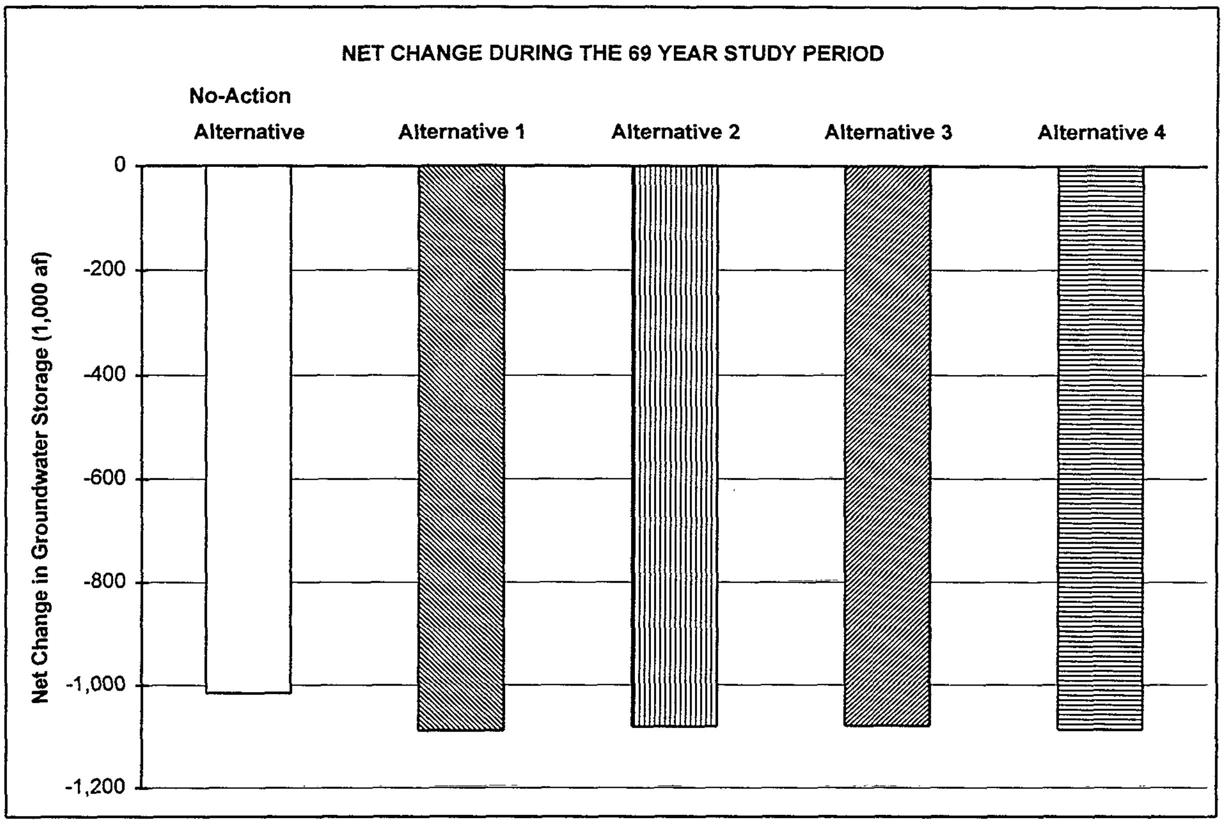

FIGURE B - 18
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 6

C-080571

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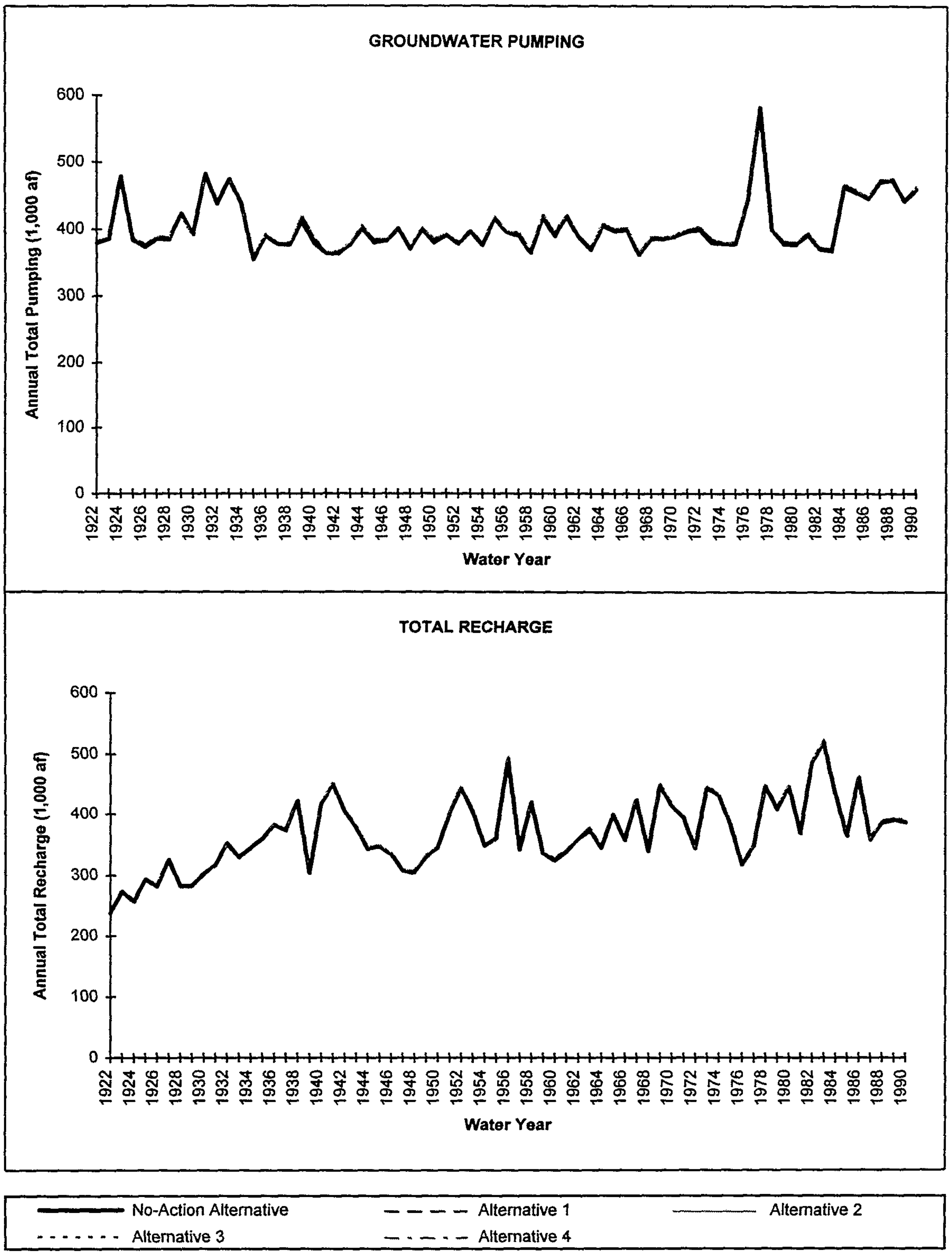

FIGURE B - 19
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 7

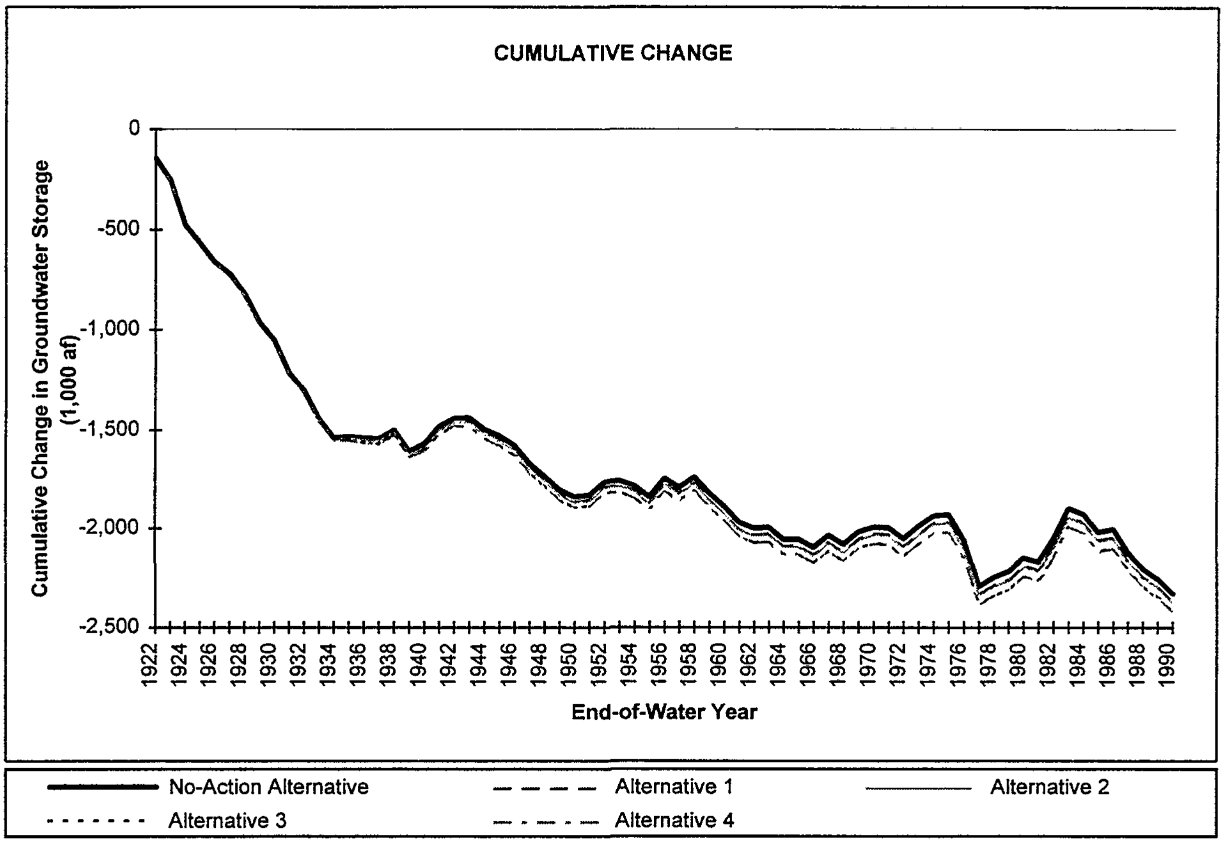

FIGURE B - 20
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 7

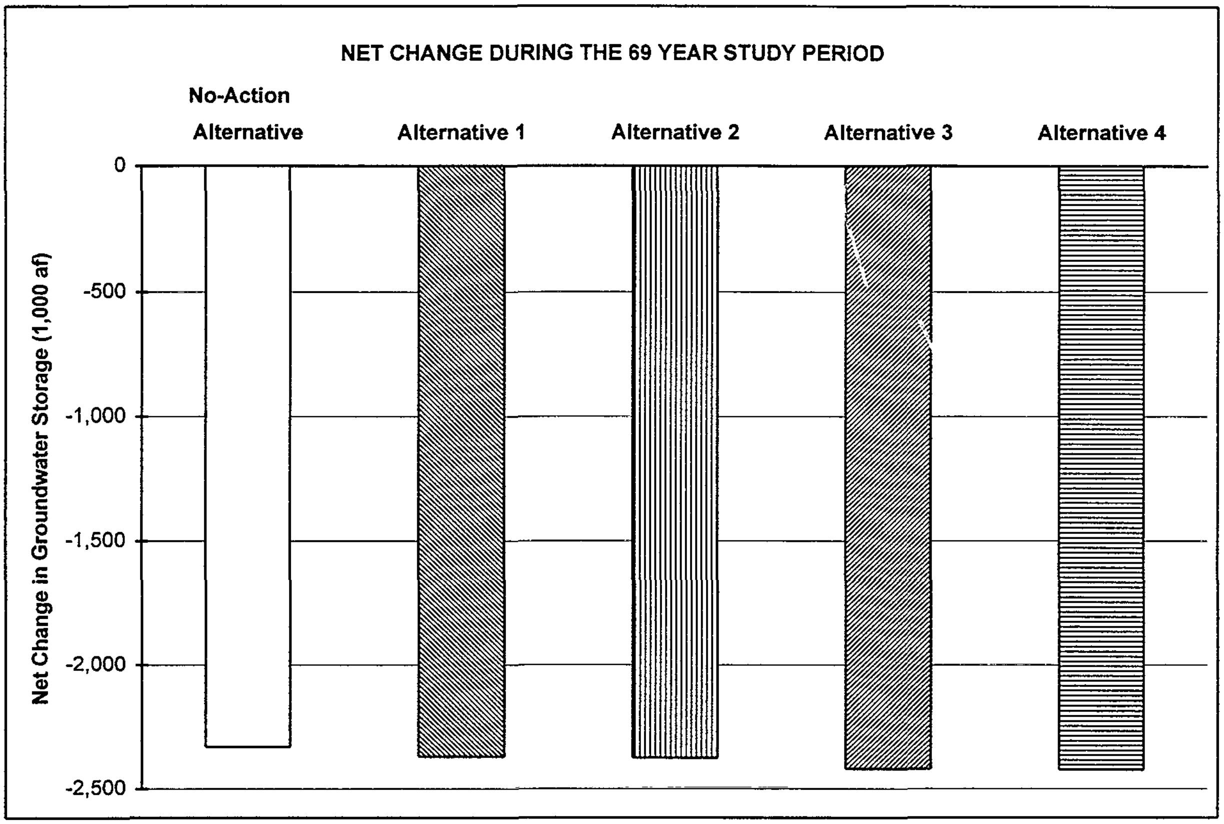

FIGURE B - 21
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 7

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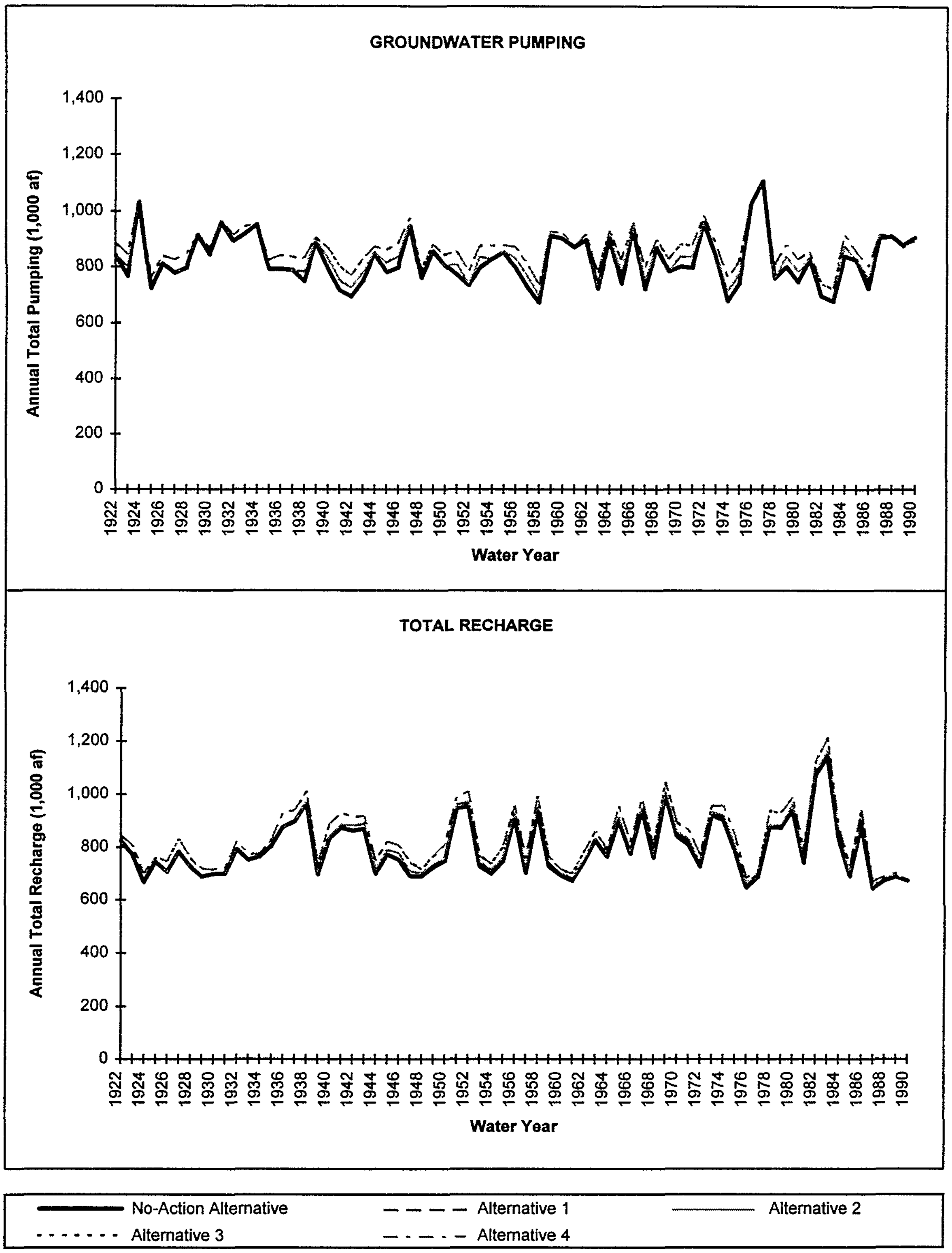

FIGURE B - 22
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 8

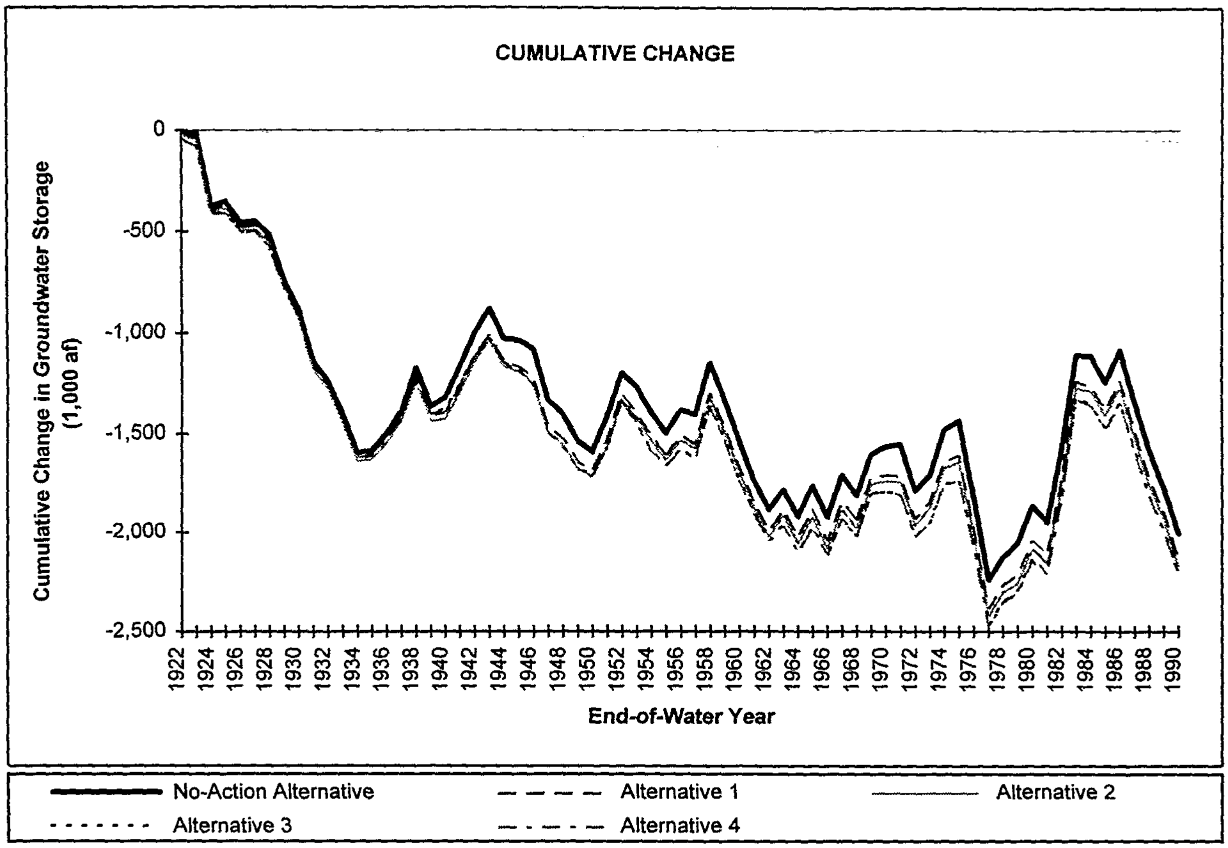

FIGURE B - 23
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 8

C — 0 8 0 5 7 8

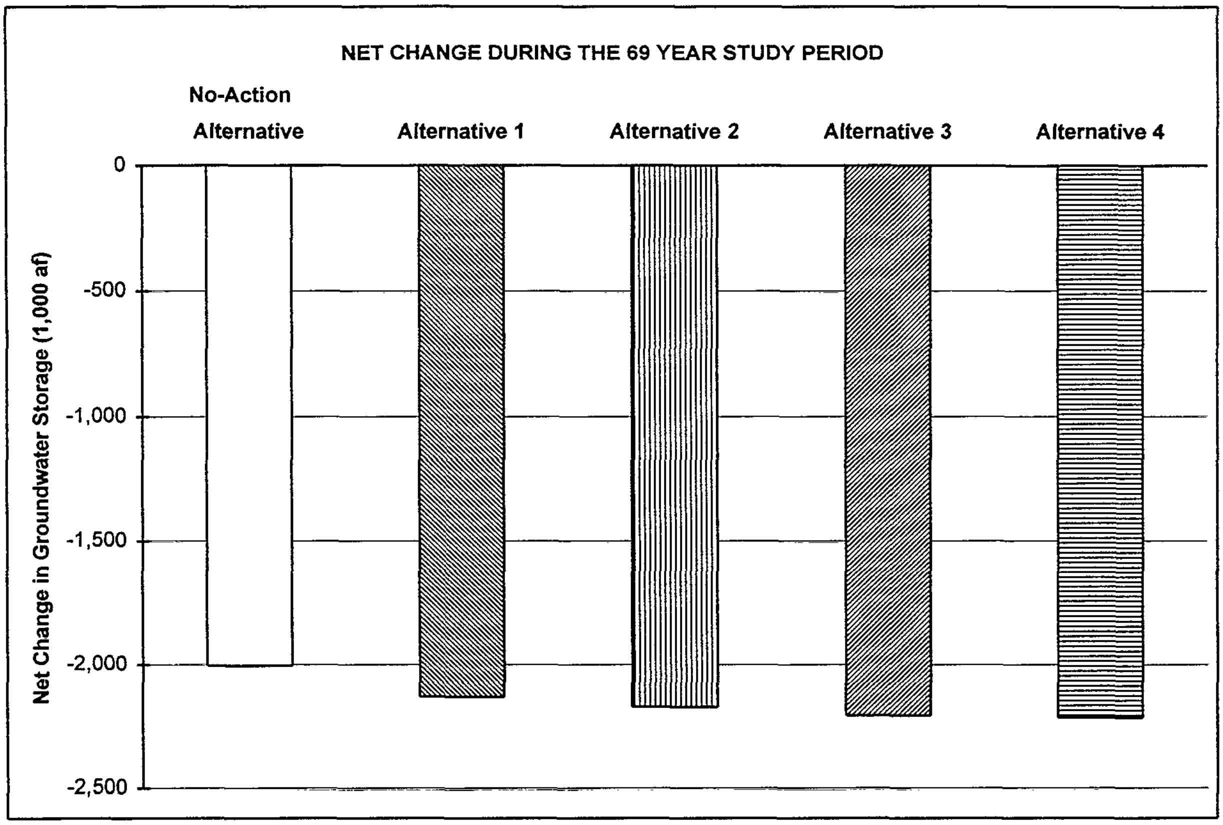

FIGURE B - 24
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 8

C–080579

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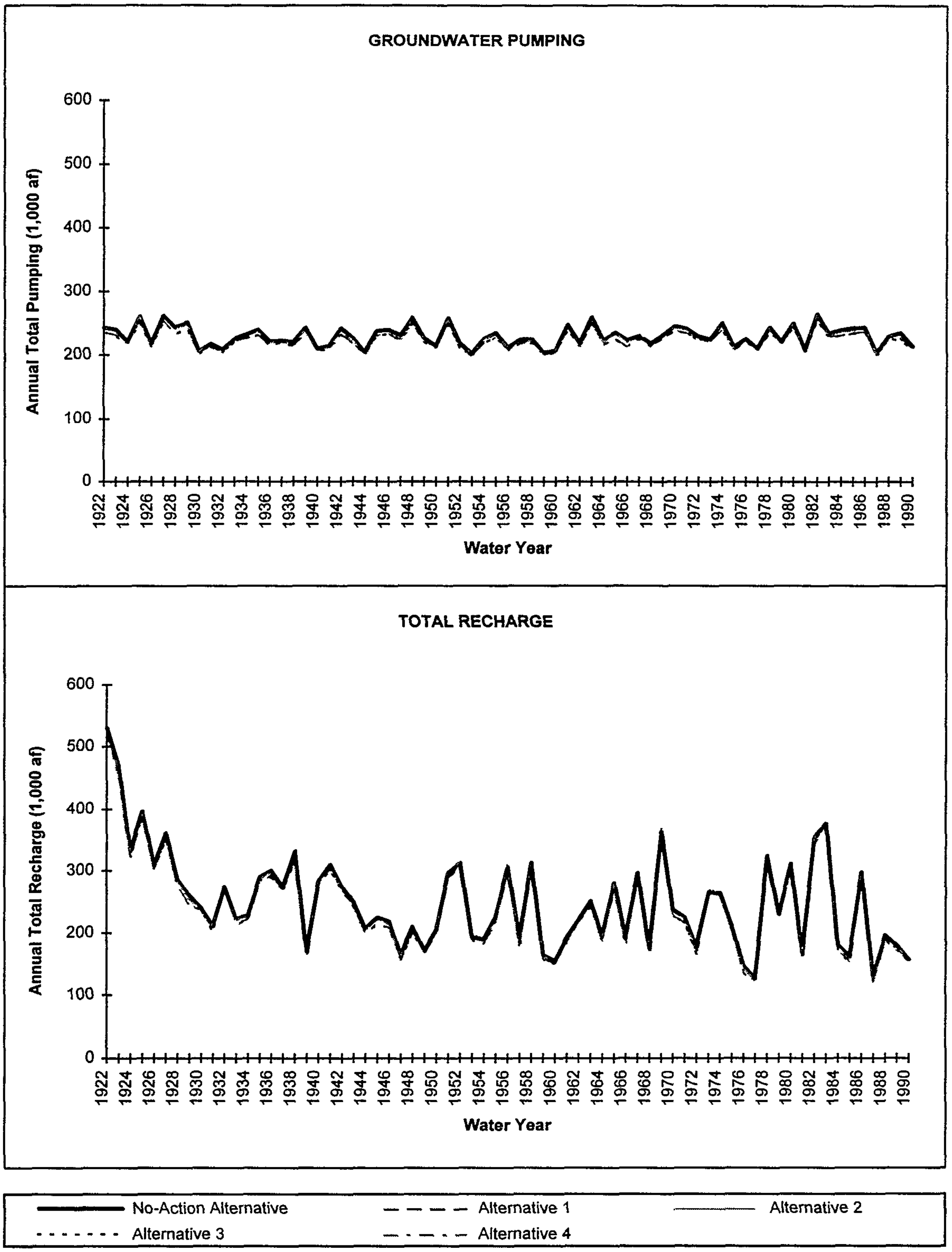

FIGURE B - 25
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 9

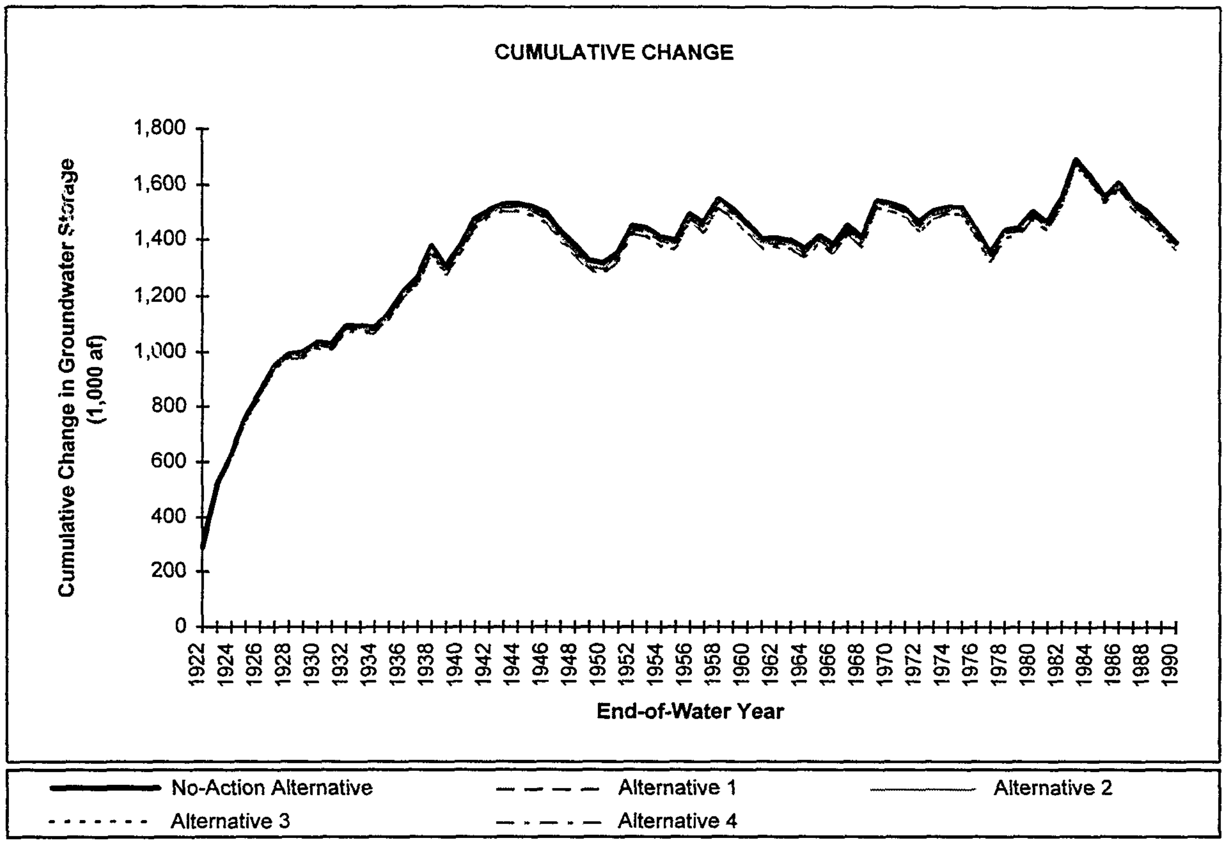

FIGURE B - 26
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 9

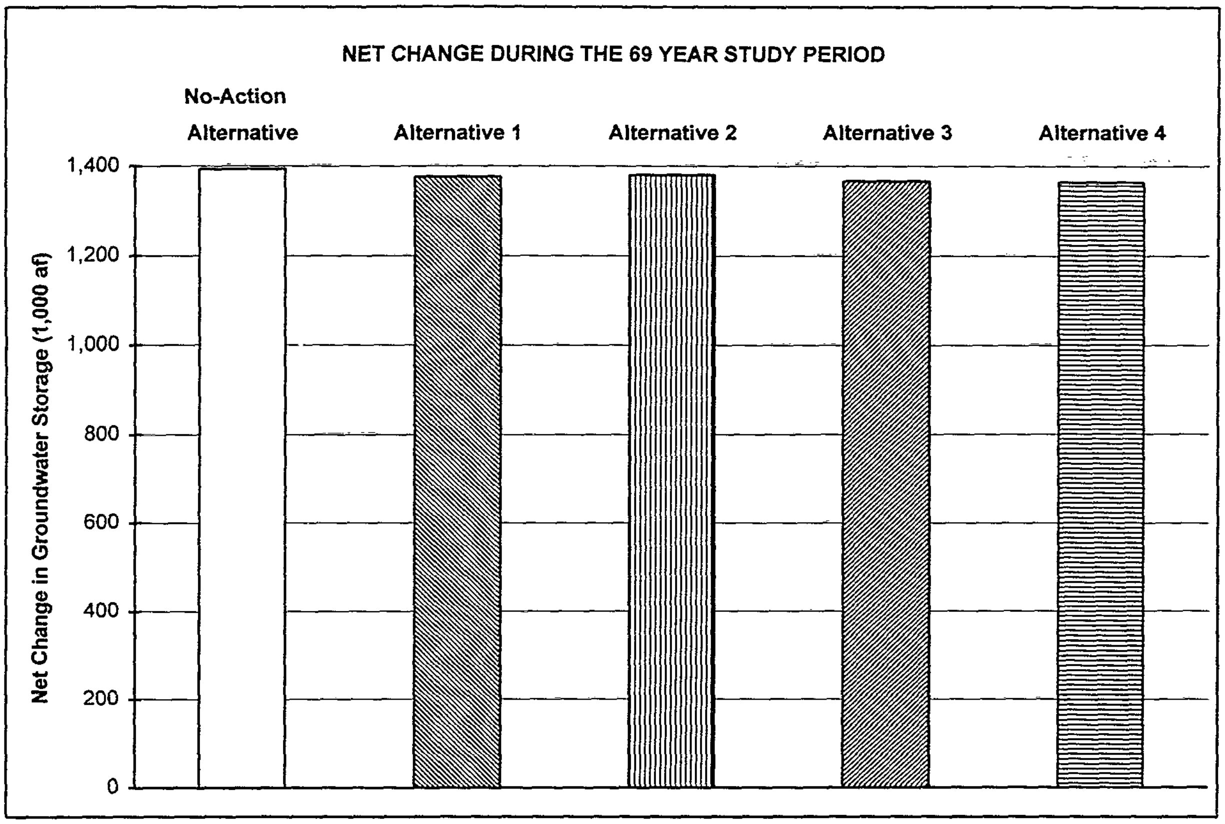

FIGURE B - 27
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 9

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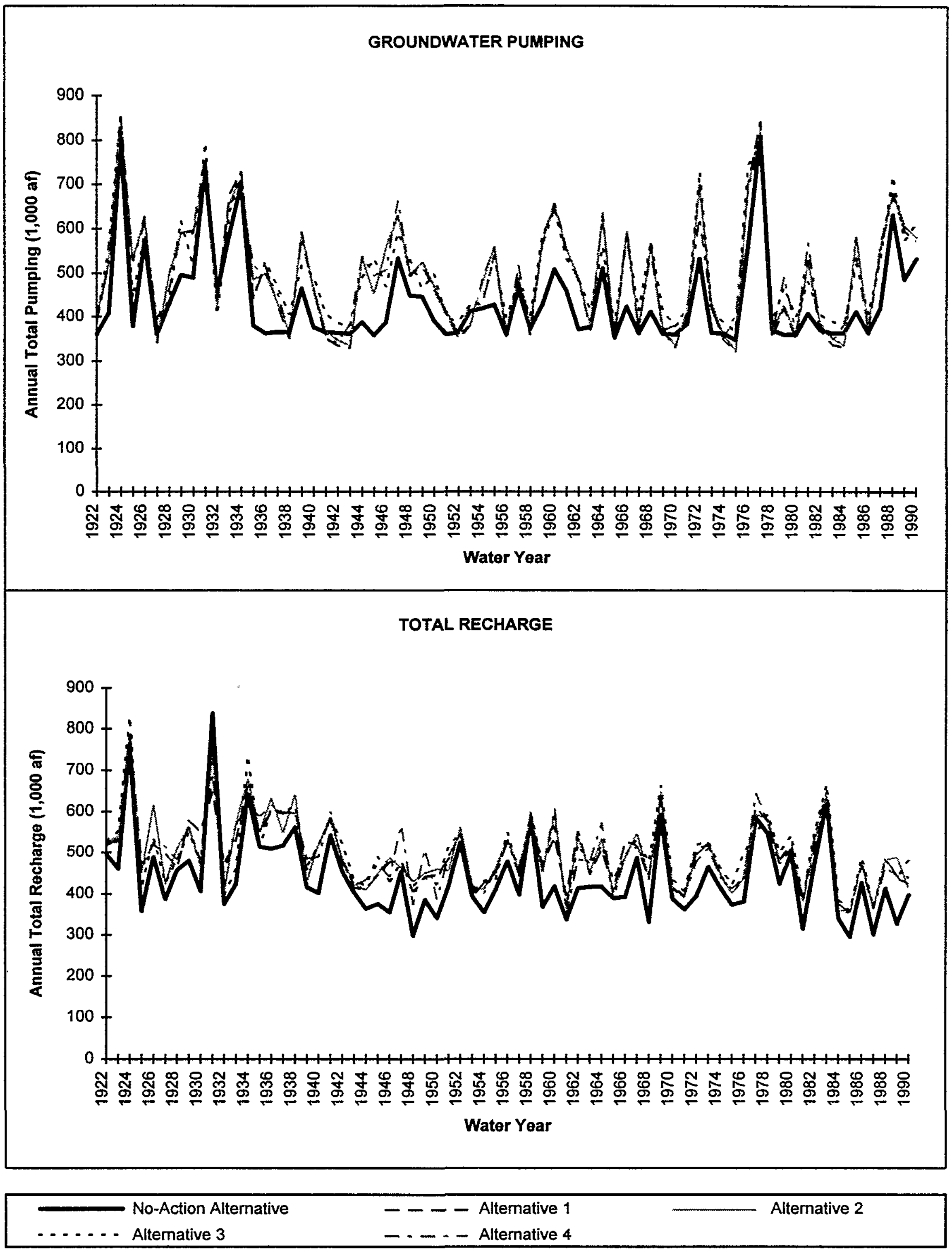

FIGURE B - 28
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 10

C—080585

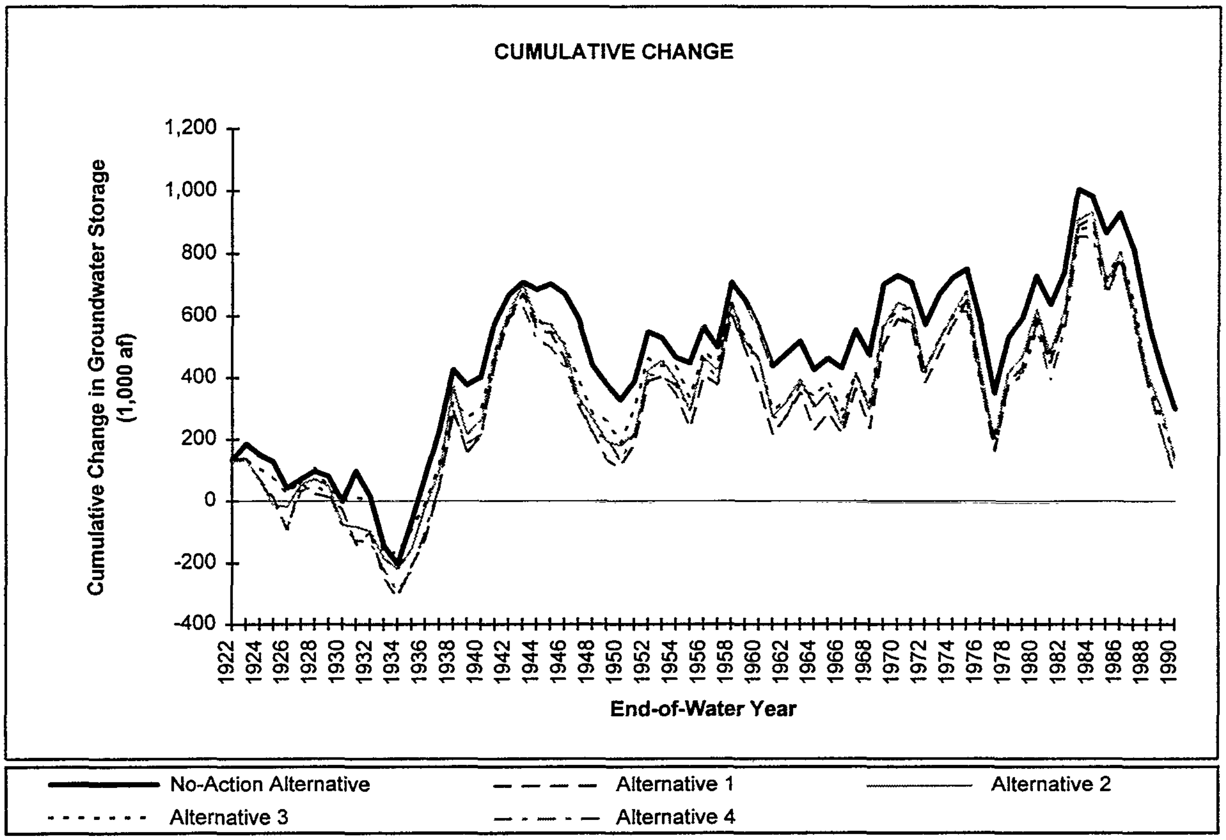

FIGURE B - 29
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 10

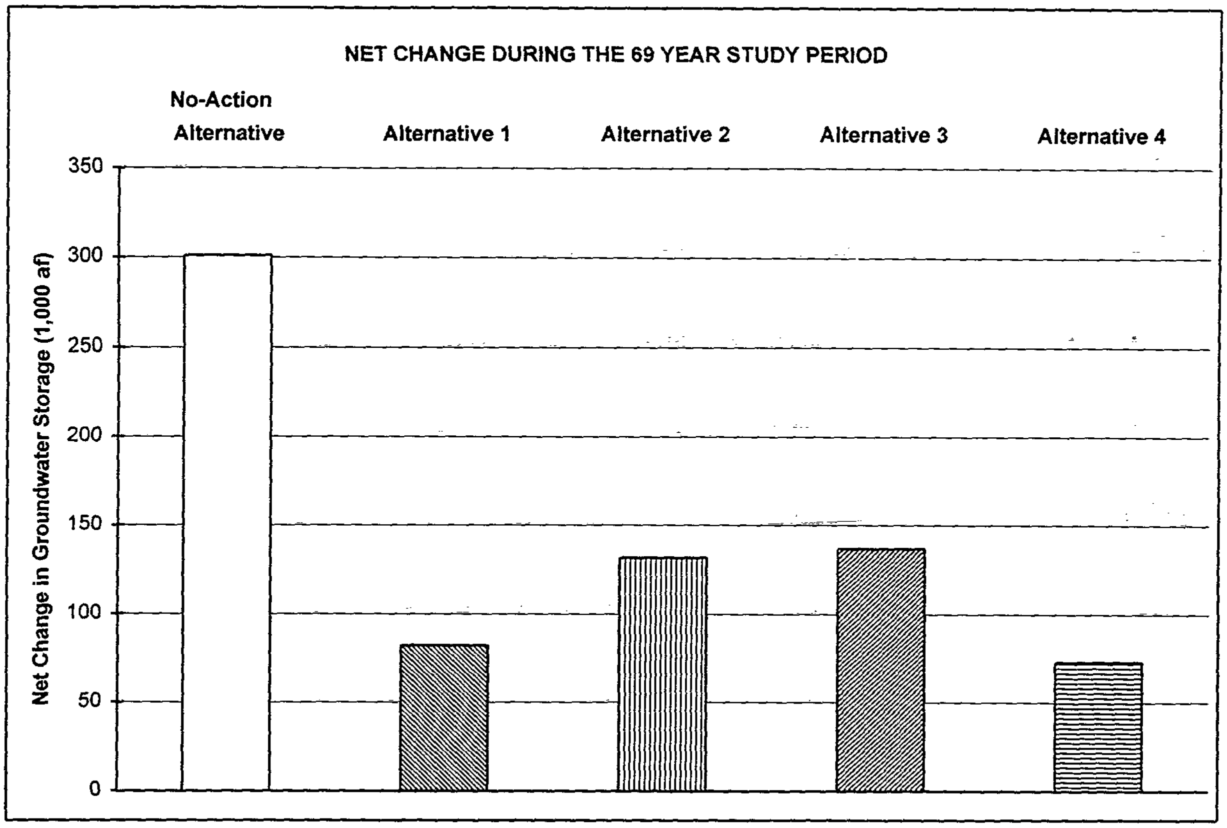

FIGURE B - 30
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 10

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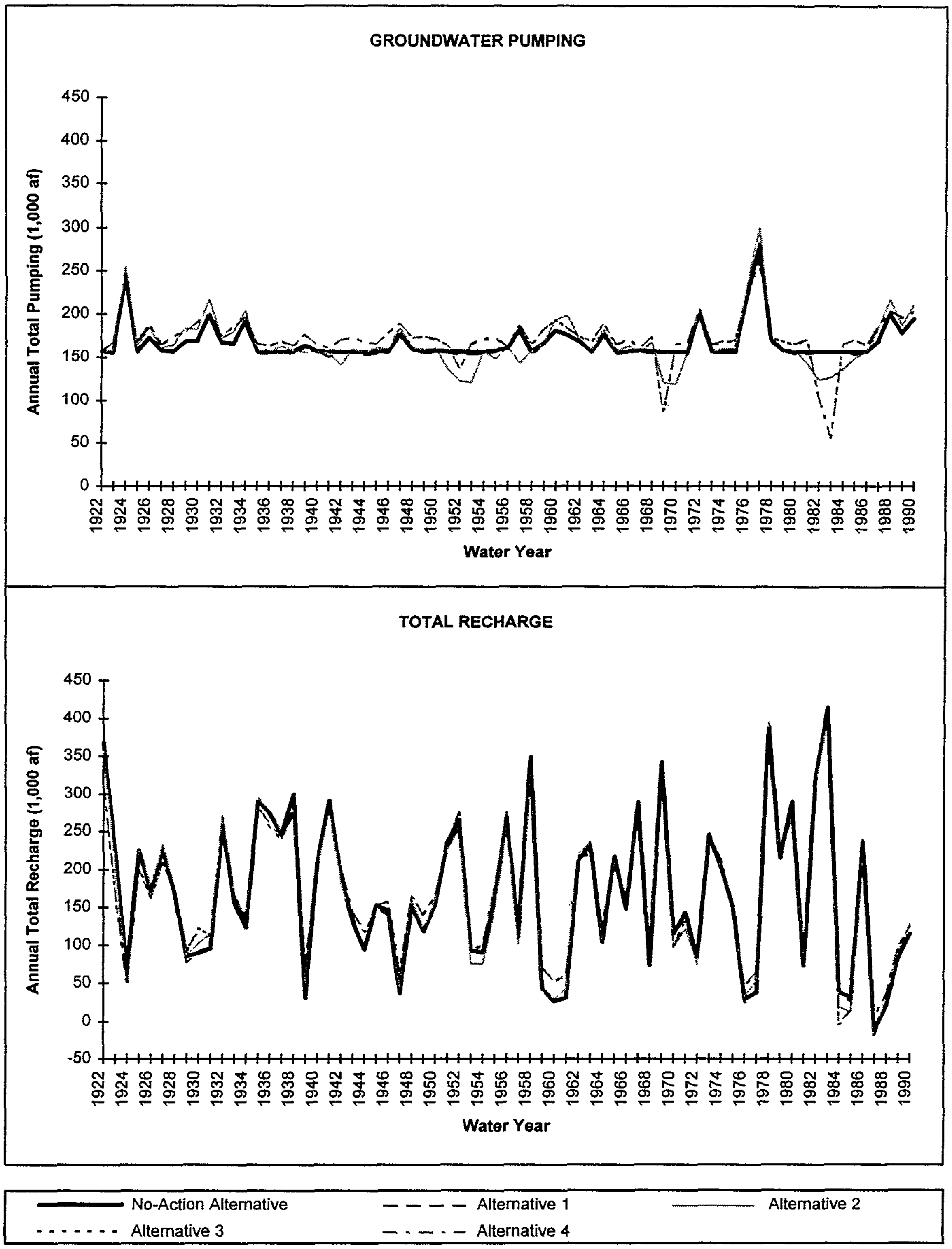

FIGURE B - 31
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 11

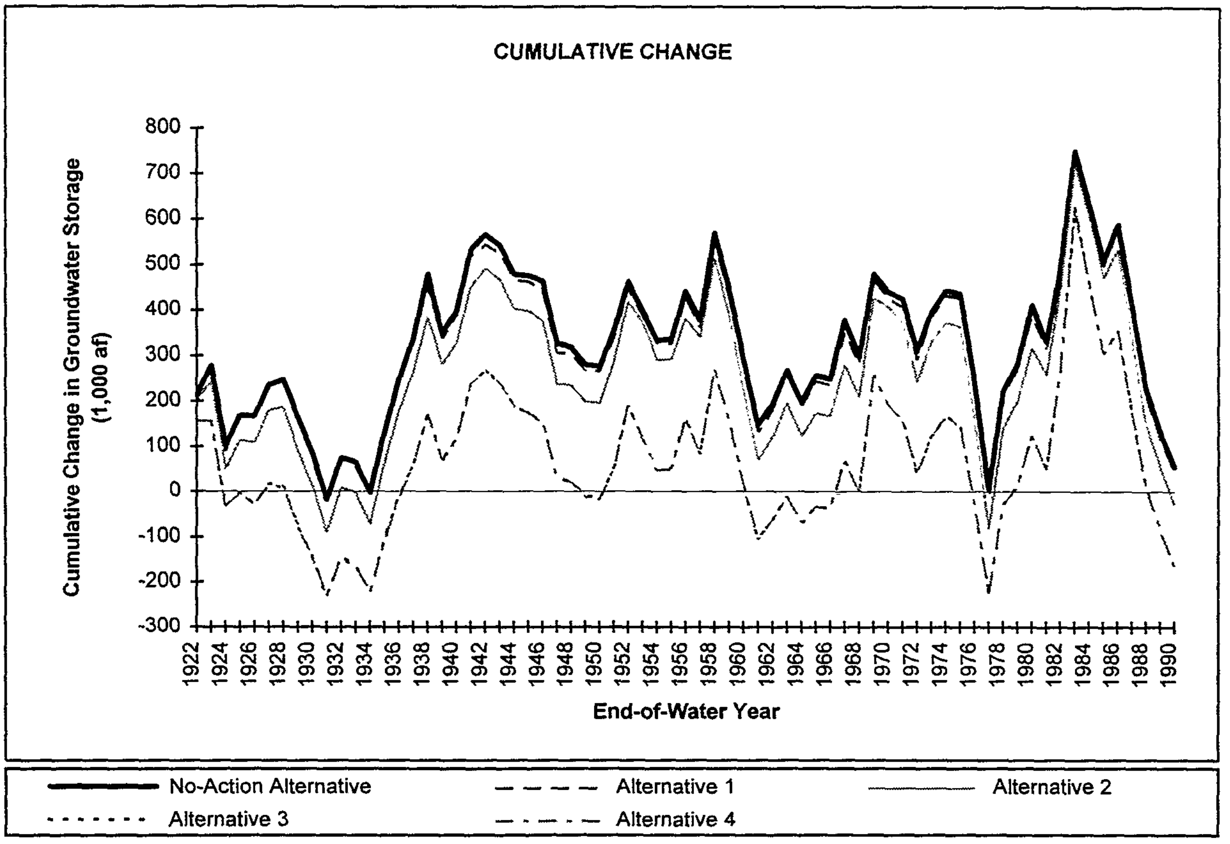

FIGURE B - 32
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 11

C — 0 8 0 5 9 0

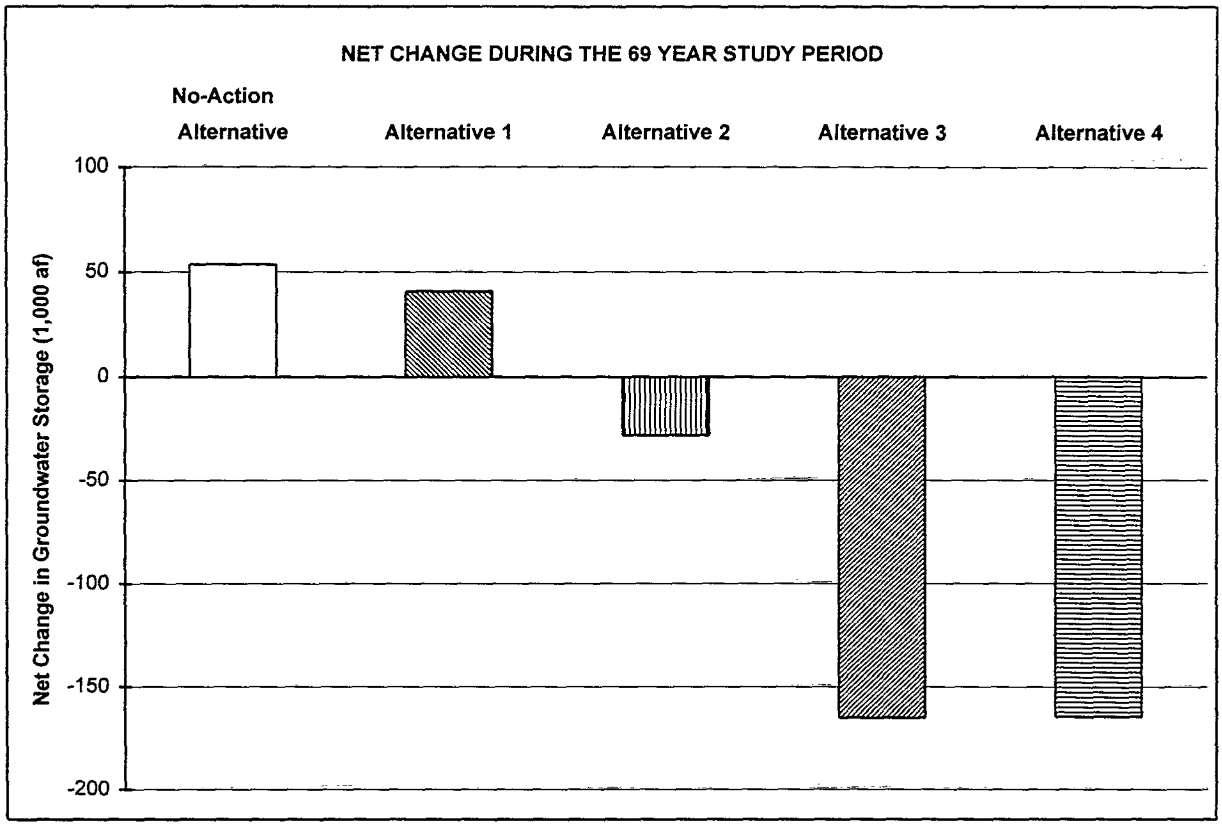

FIGURE B - 33
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 11

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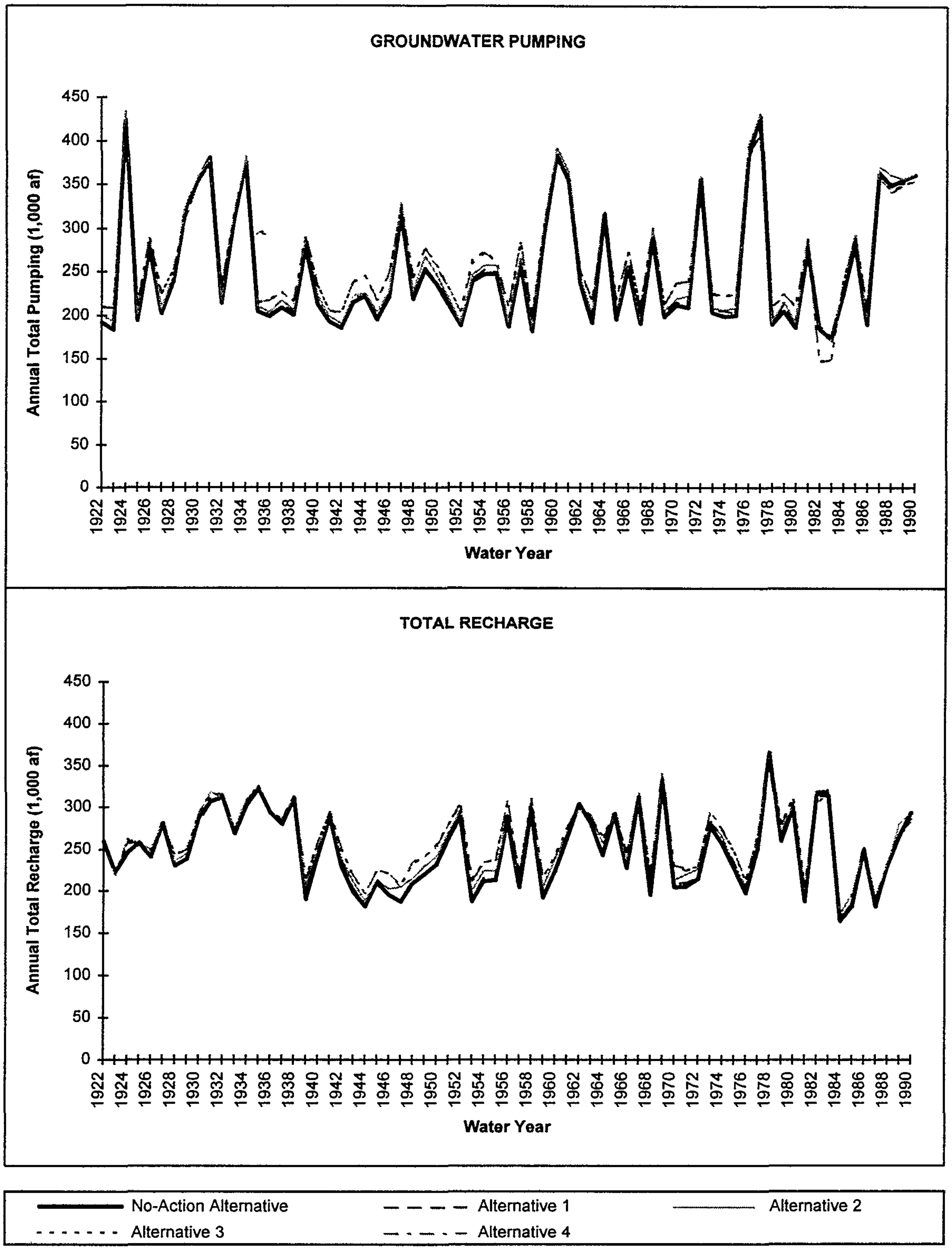

FIGURE B - 34
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 12

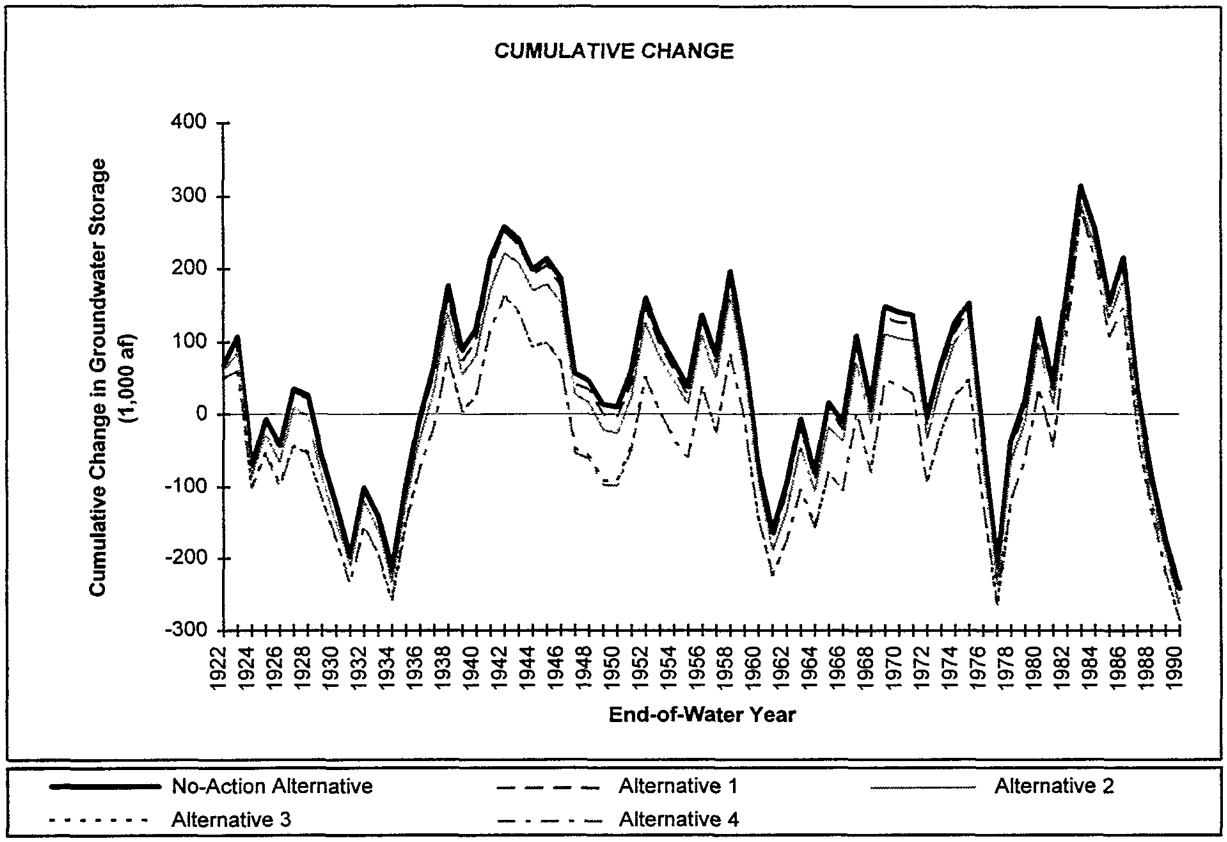

FIGURE B - 35
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 12

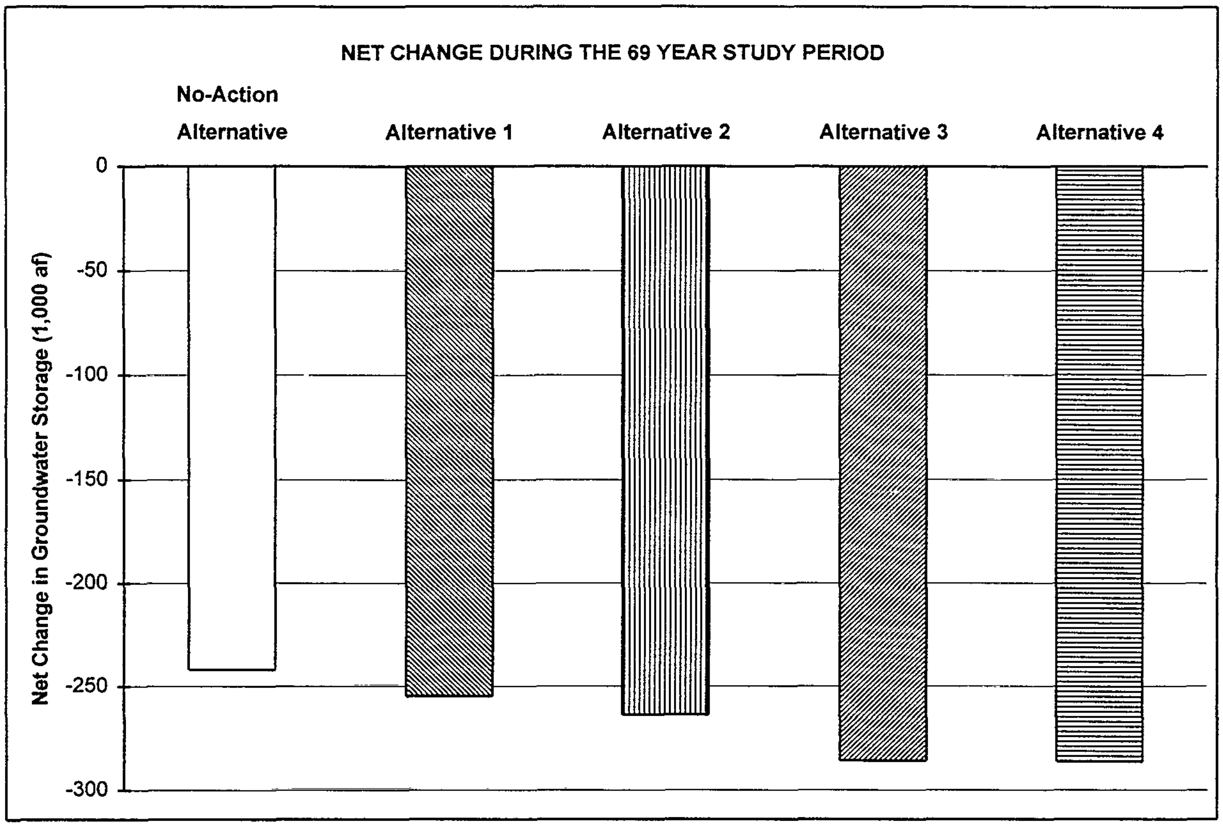

FIGURE B - 36
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 12

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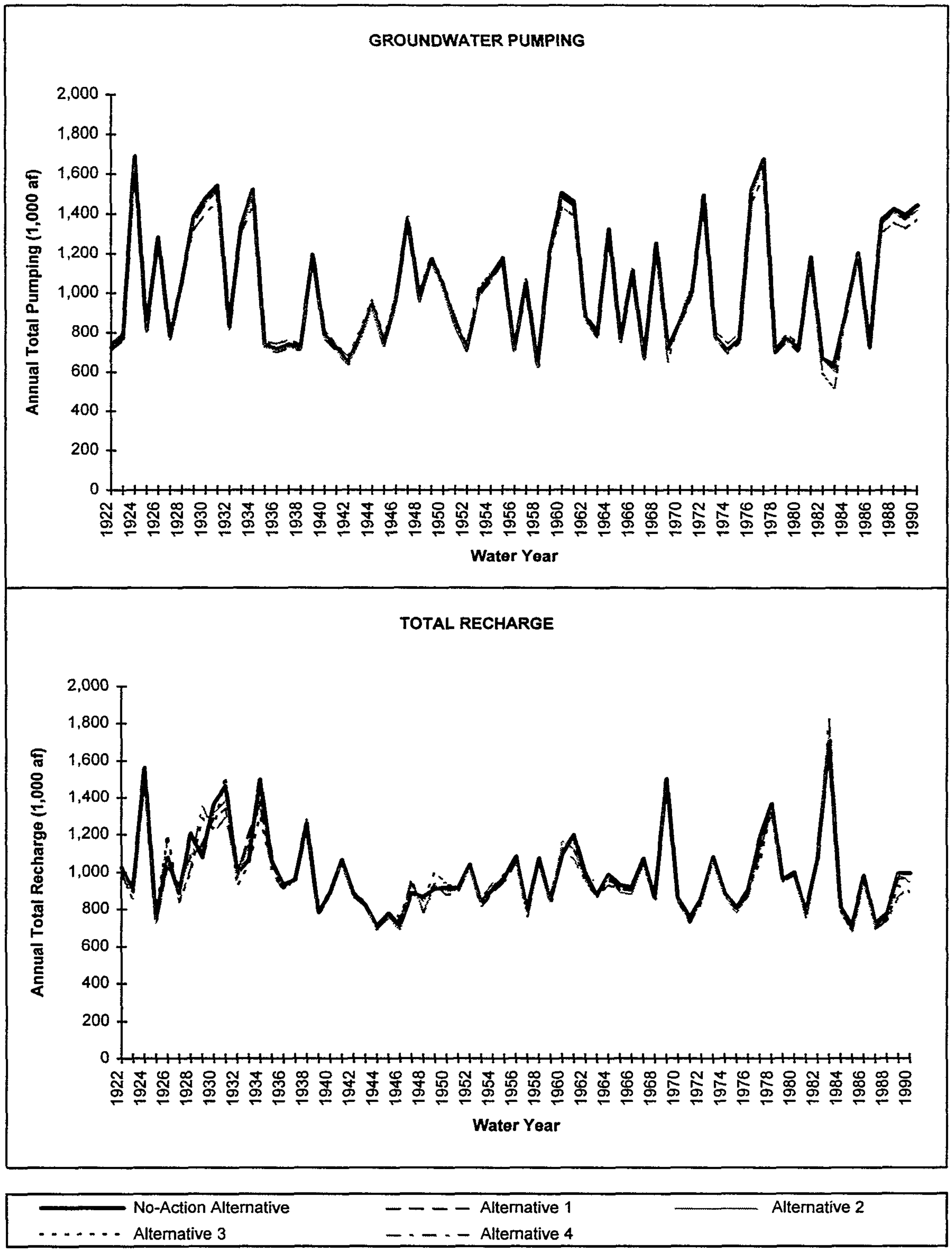

FIGURE B - 37
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 13

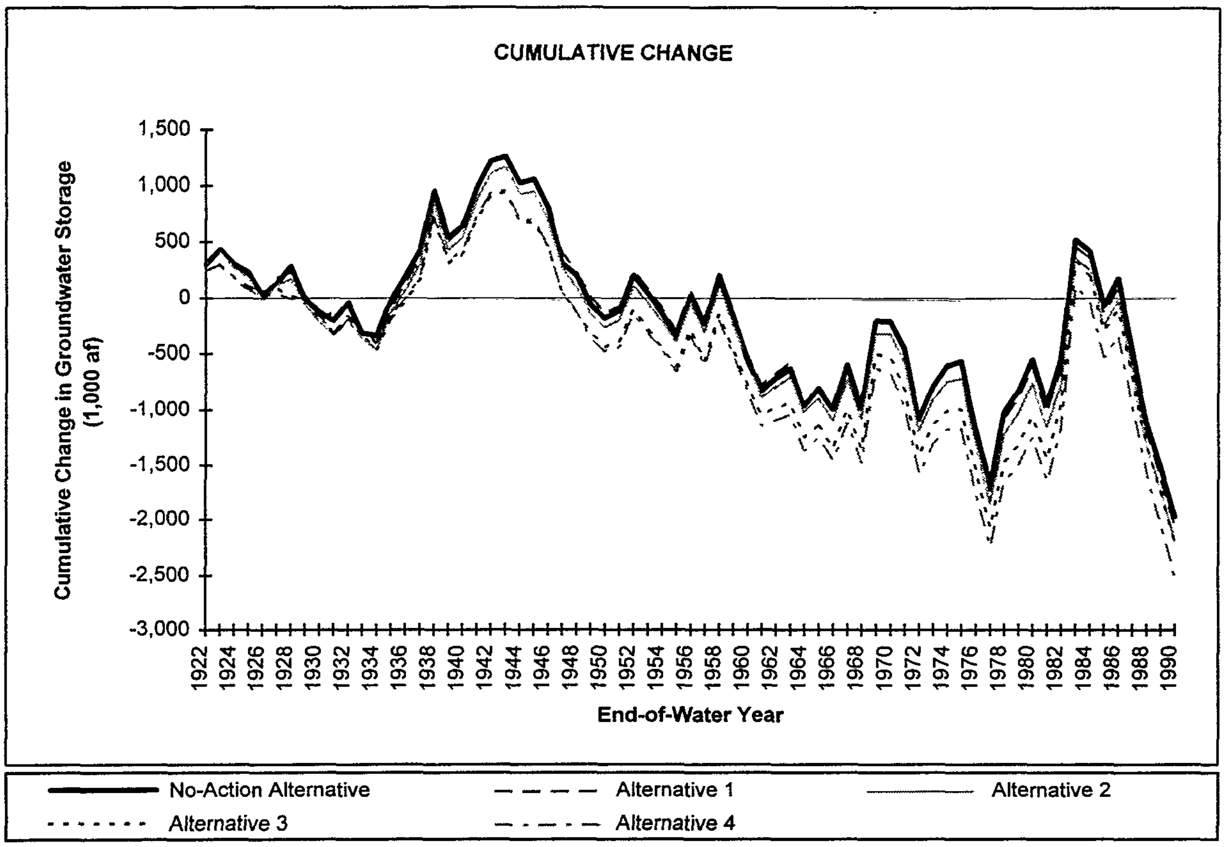

FIGURE B - 38
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 13

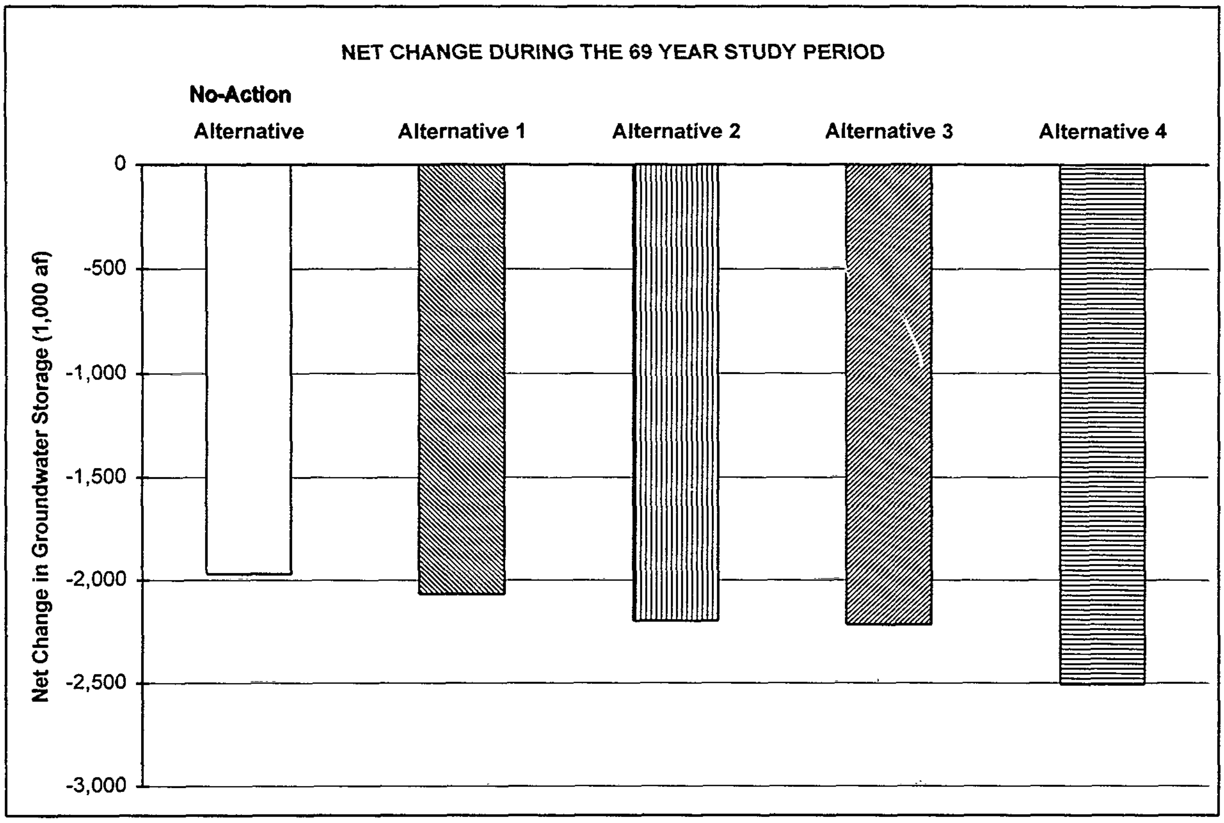

FIGURE B - 39
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 13

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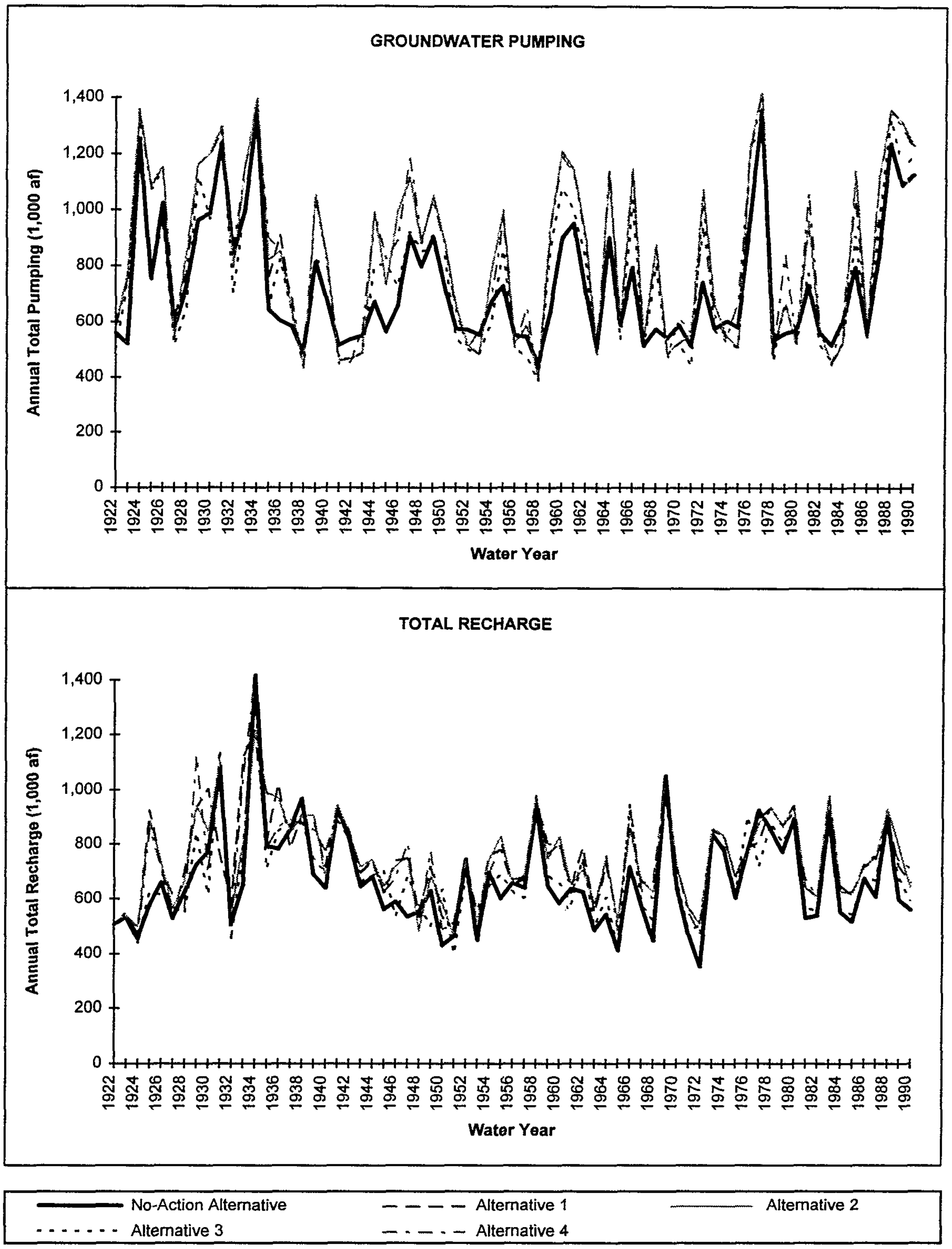

FIGURE B - 40
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 14

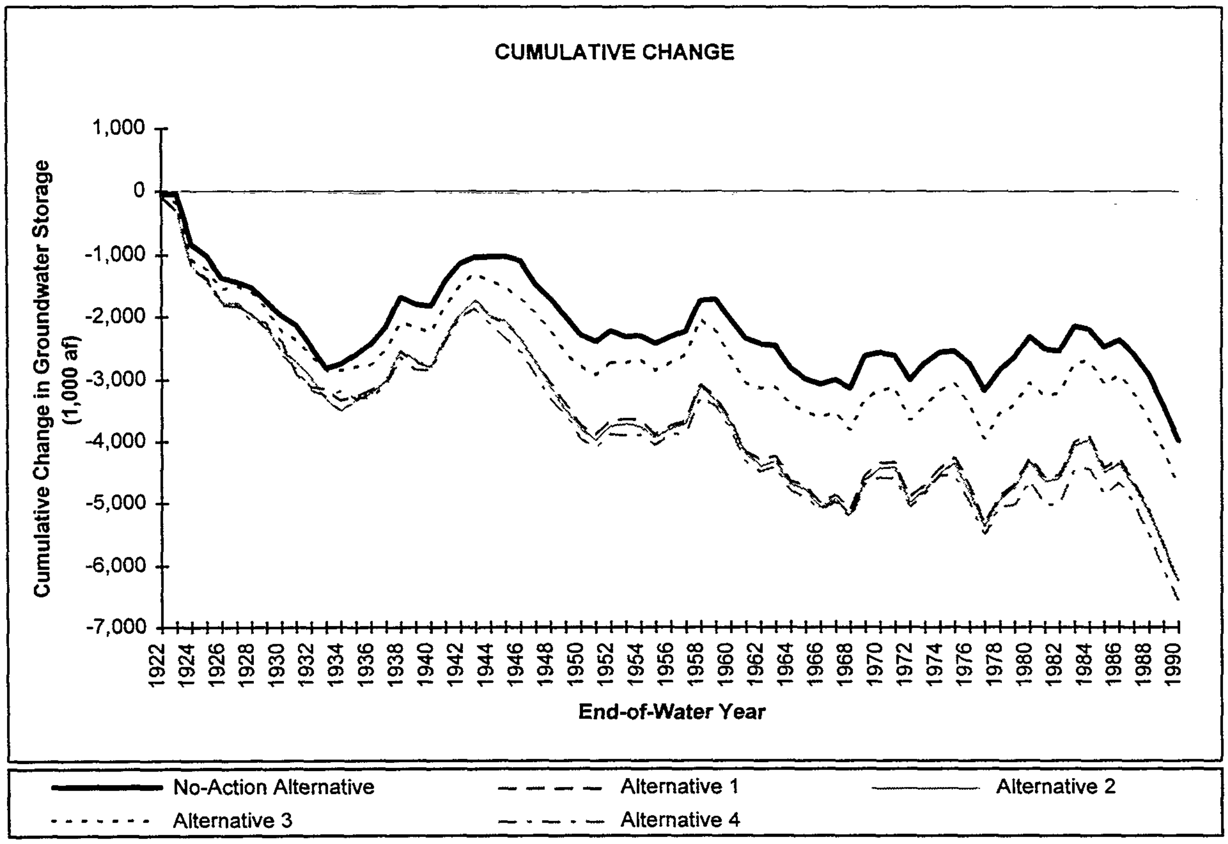

FIGURE B - 41
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 14

C — 0 8 0 6 0 2

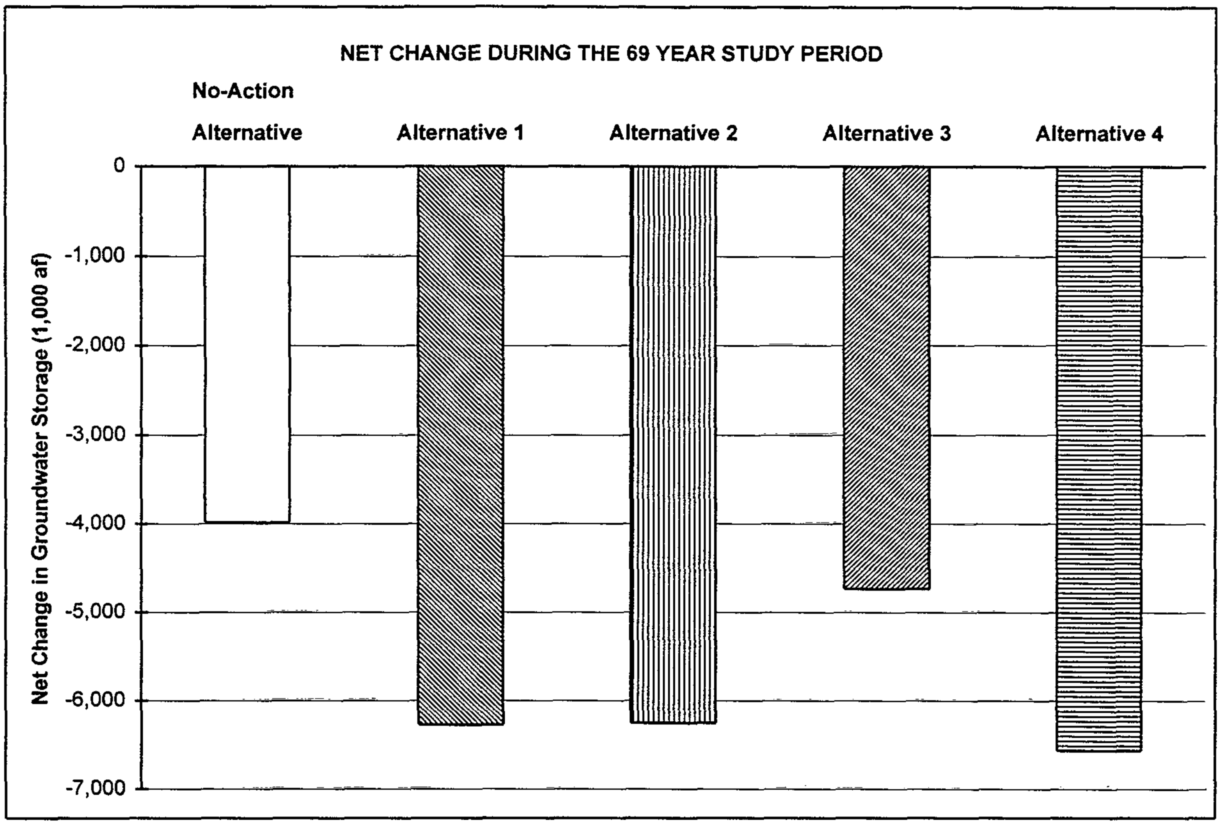

FIGURE B - 42
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 14

C —0 8 0 6 0 3

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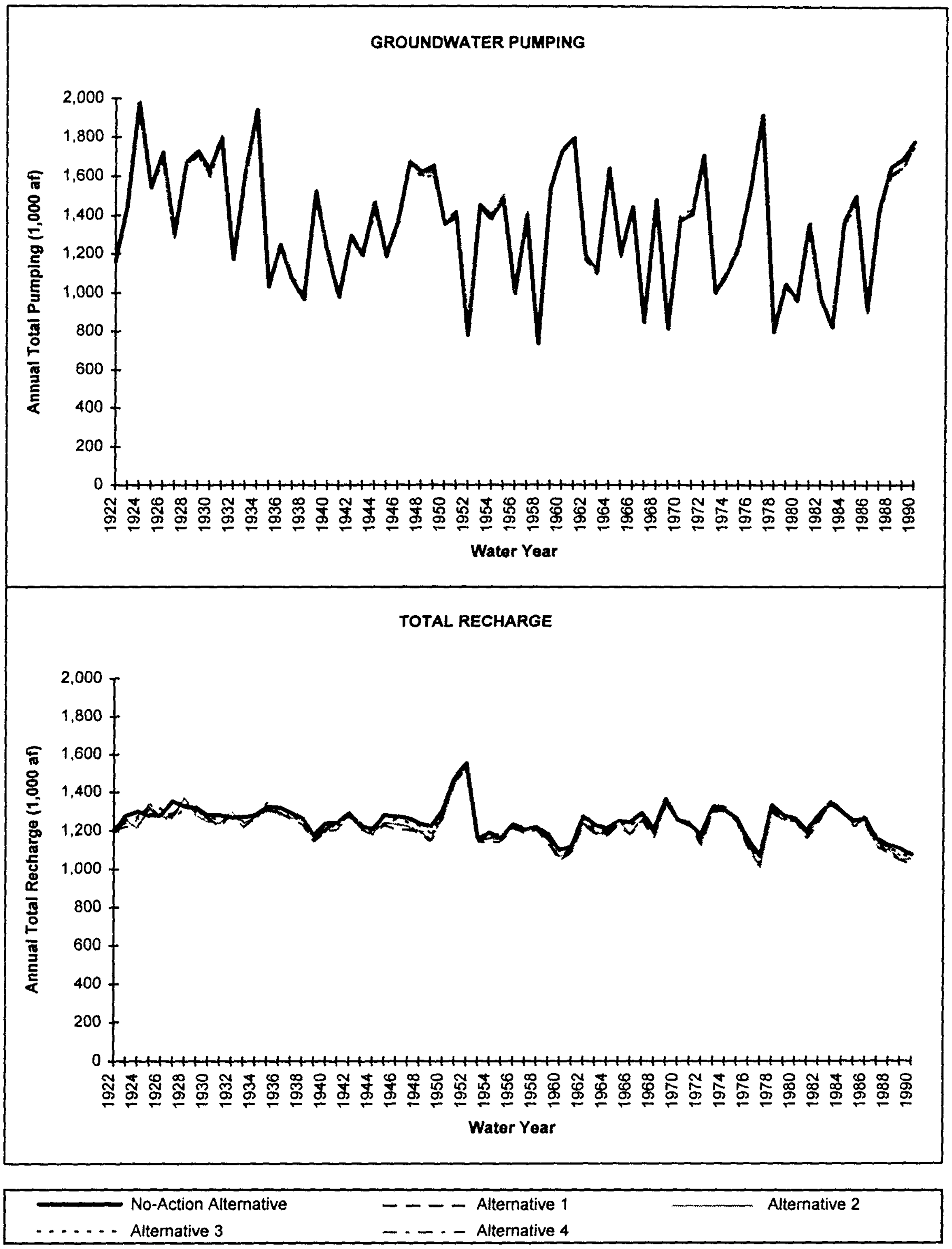

FIGURE B - 43
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 15

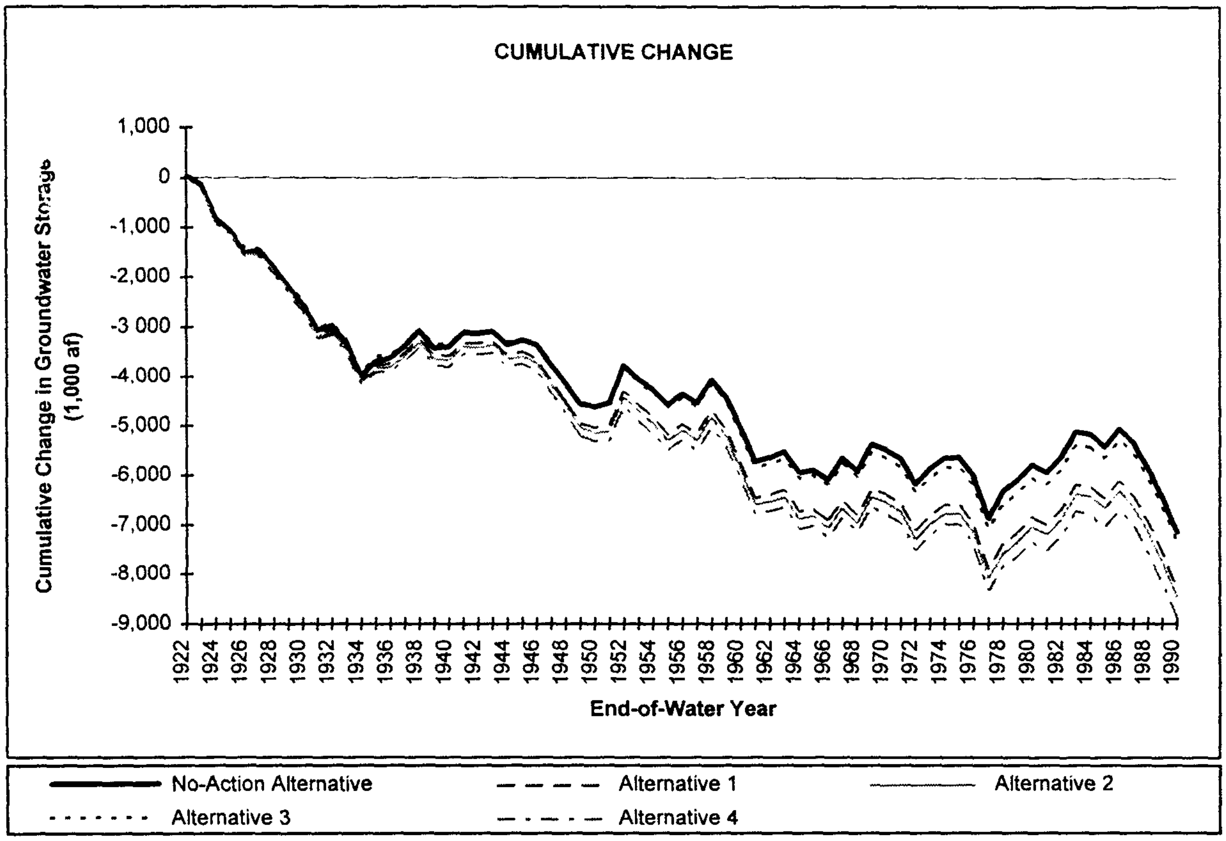

FIGURE B - 44
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 15

C —0 8 0 6 0 6

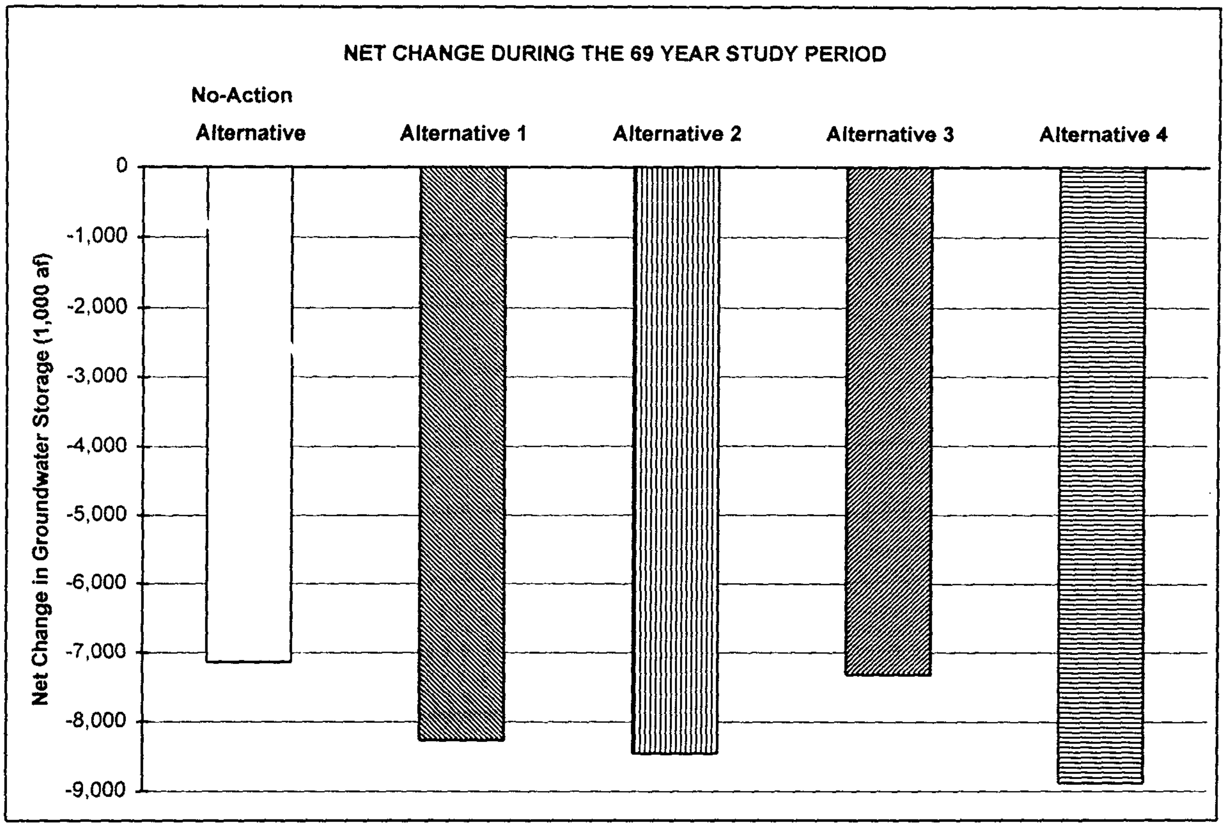

FIGURE B - 45
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 15

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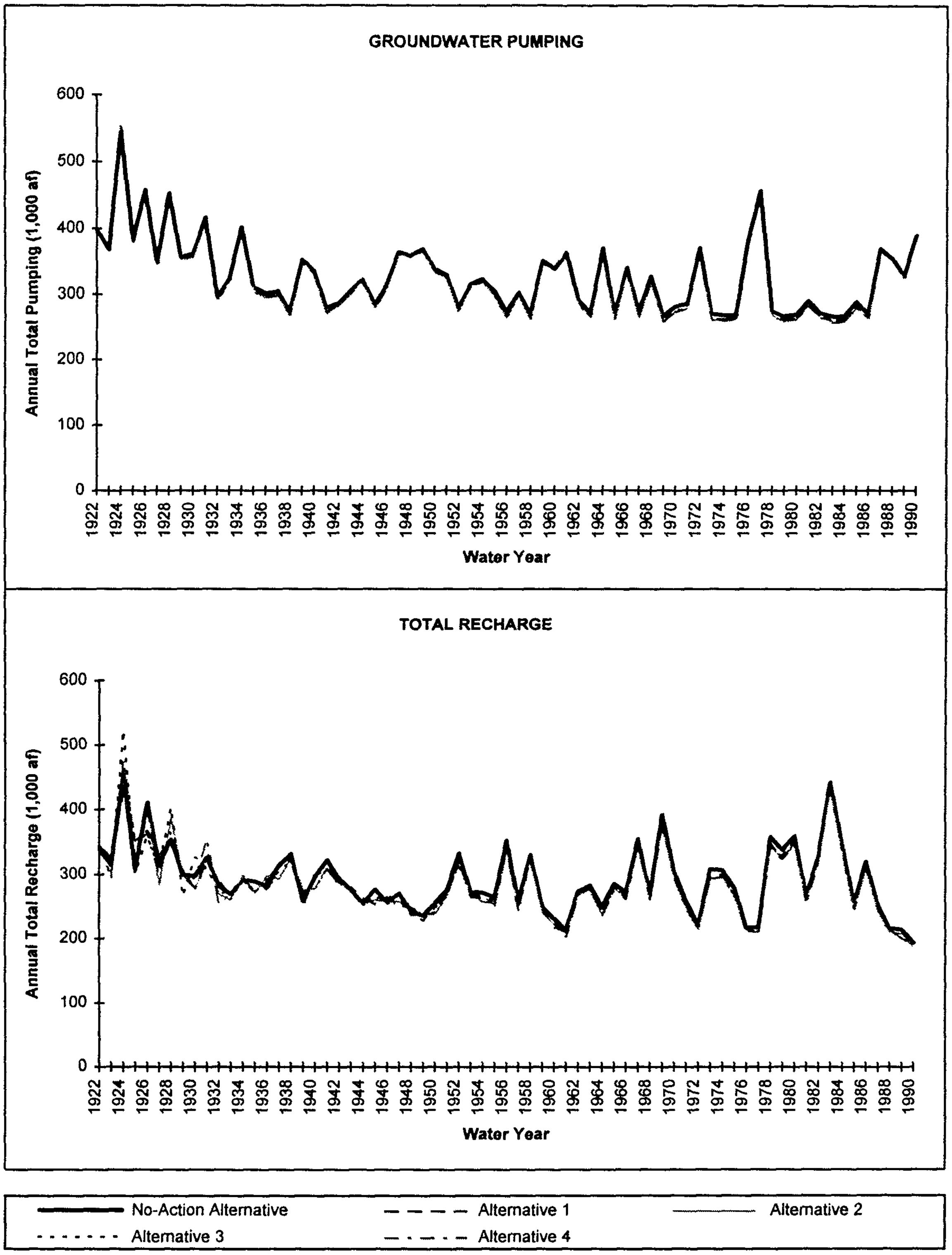

FIGURE B - 46
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 16

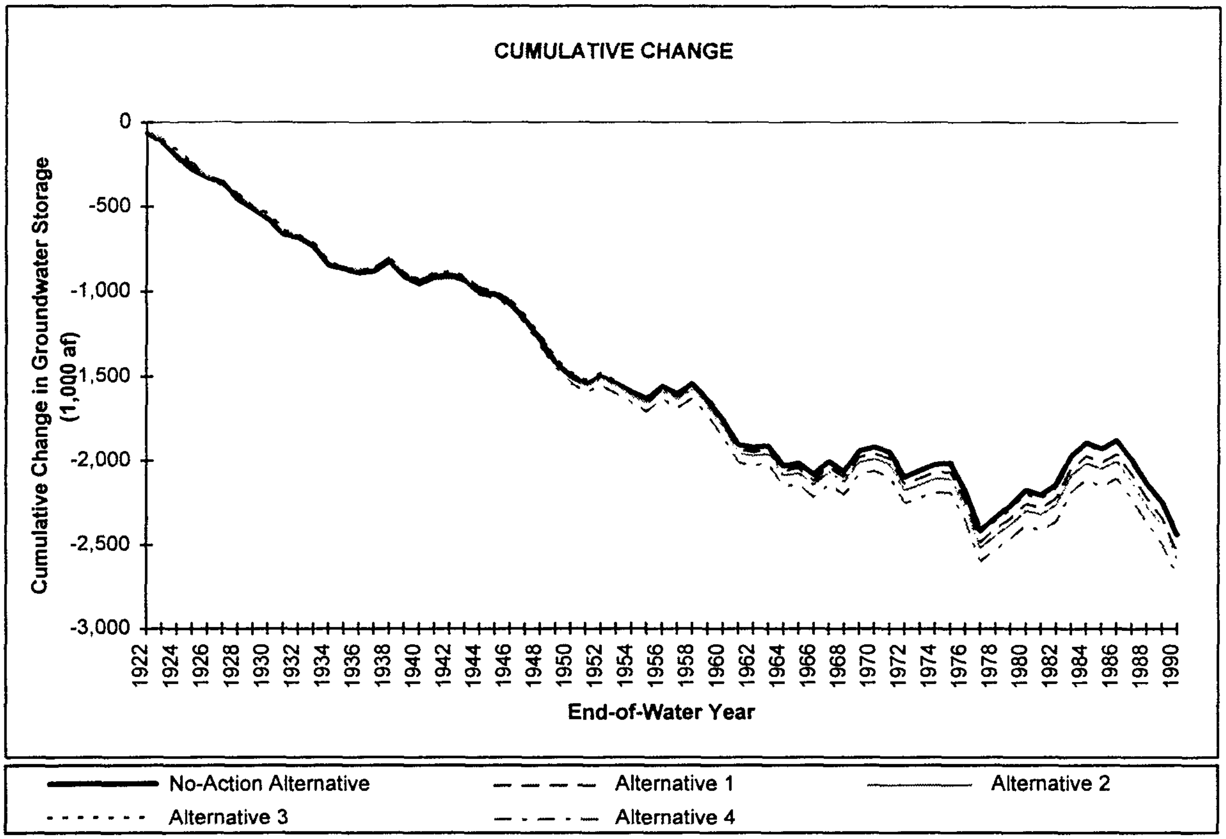

FIGURE B - 47
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 16

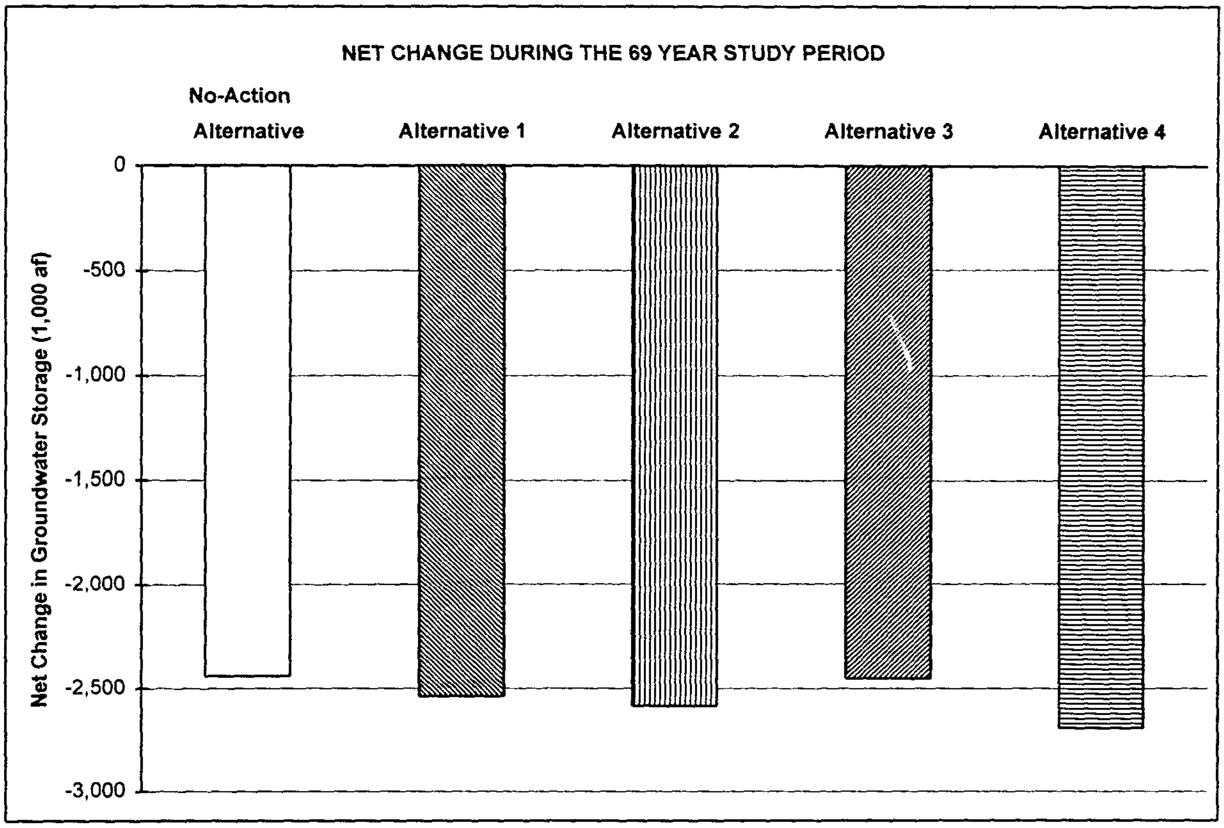

FIGURE B - 48
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 16

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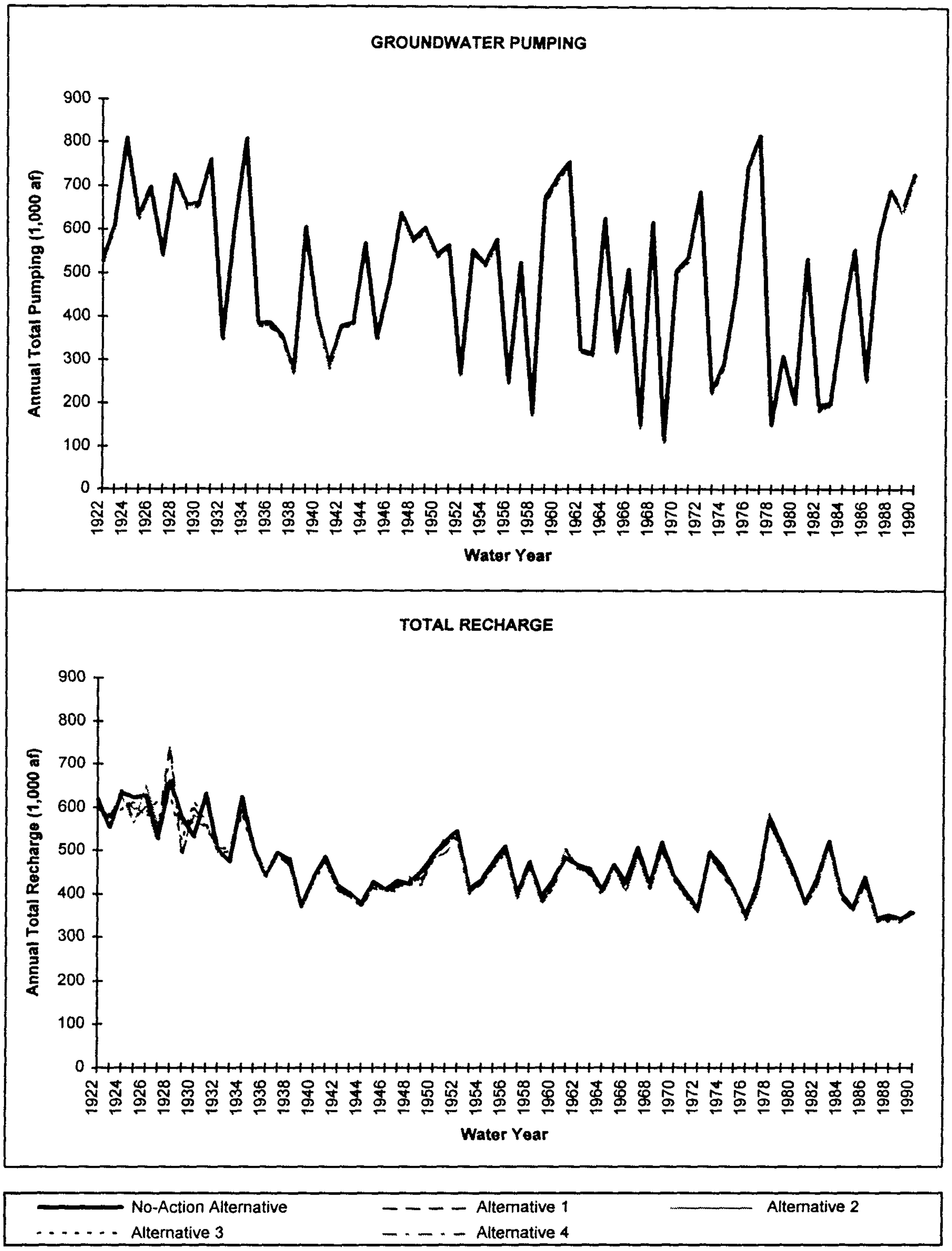

FIGURE B - 49
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 17

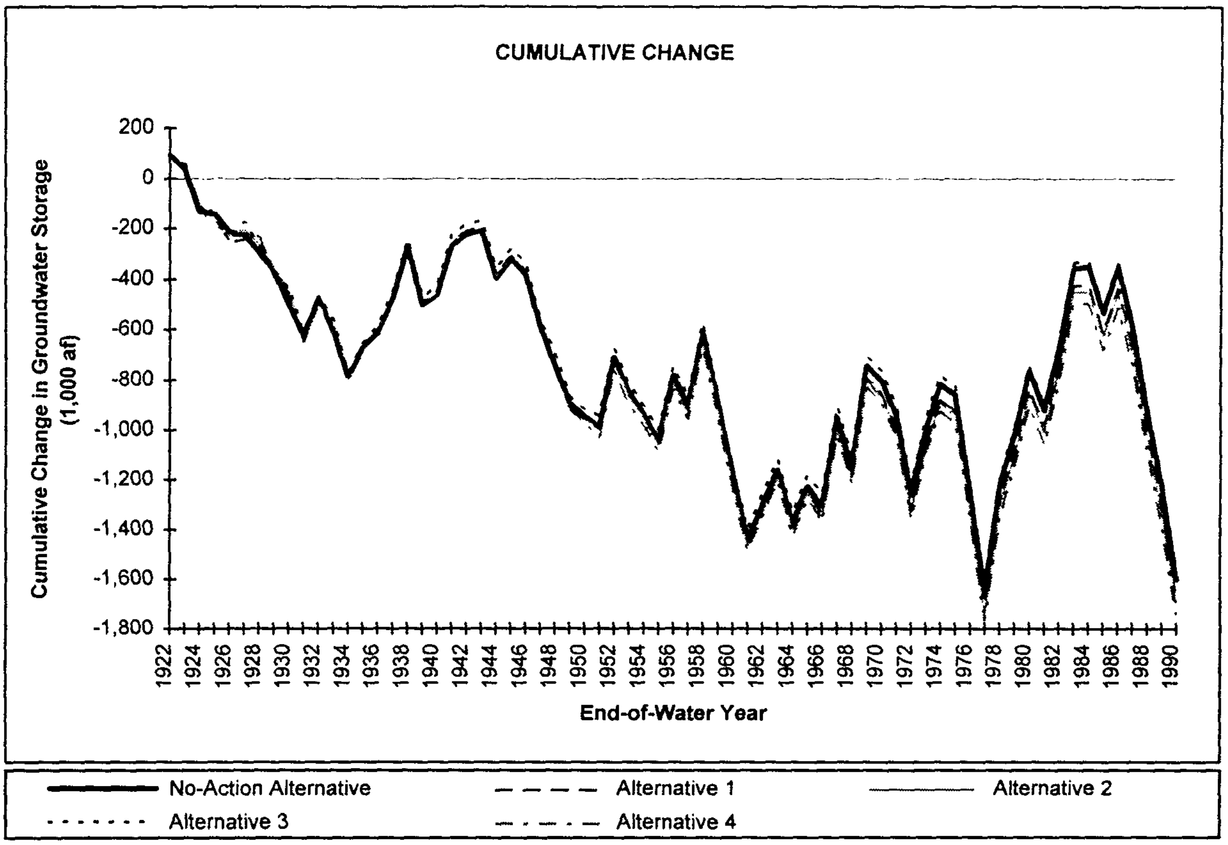

FIGURE B - 50
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 17

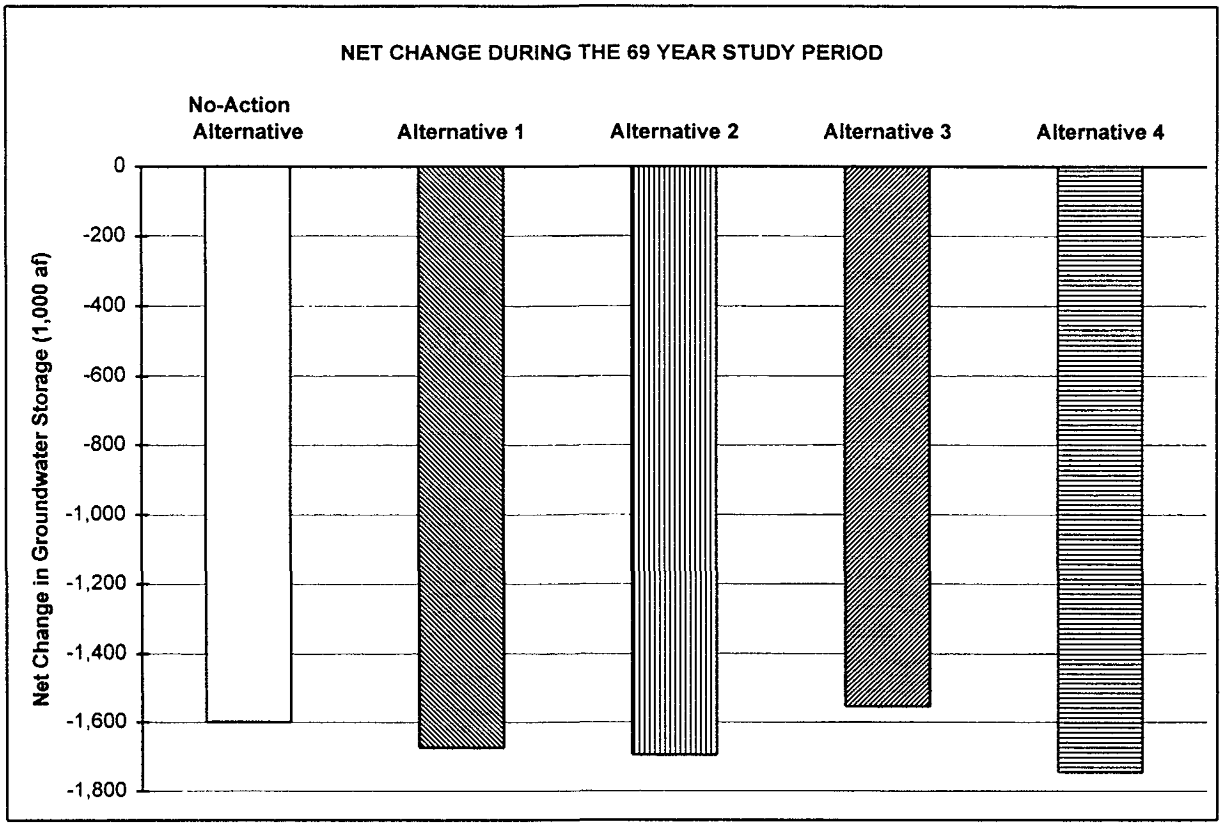

FIGURE B - 51
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 17

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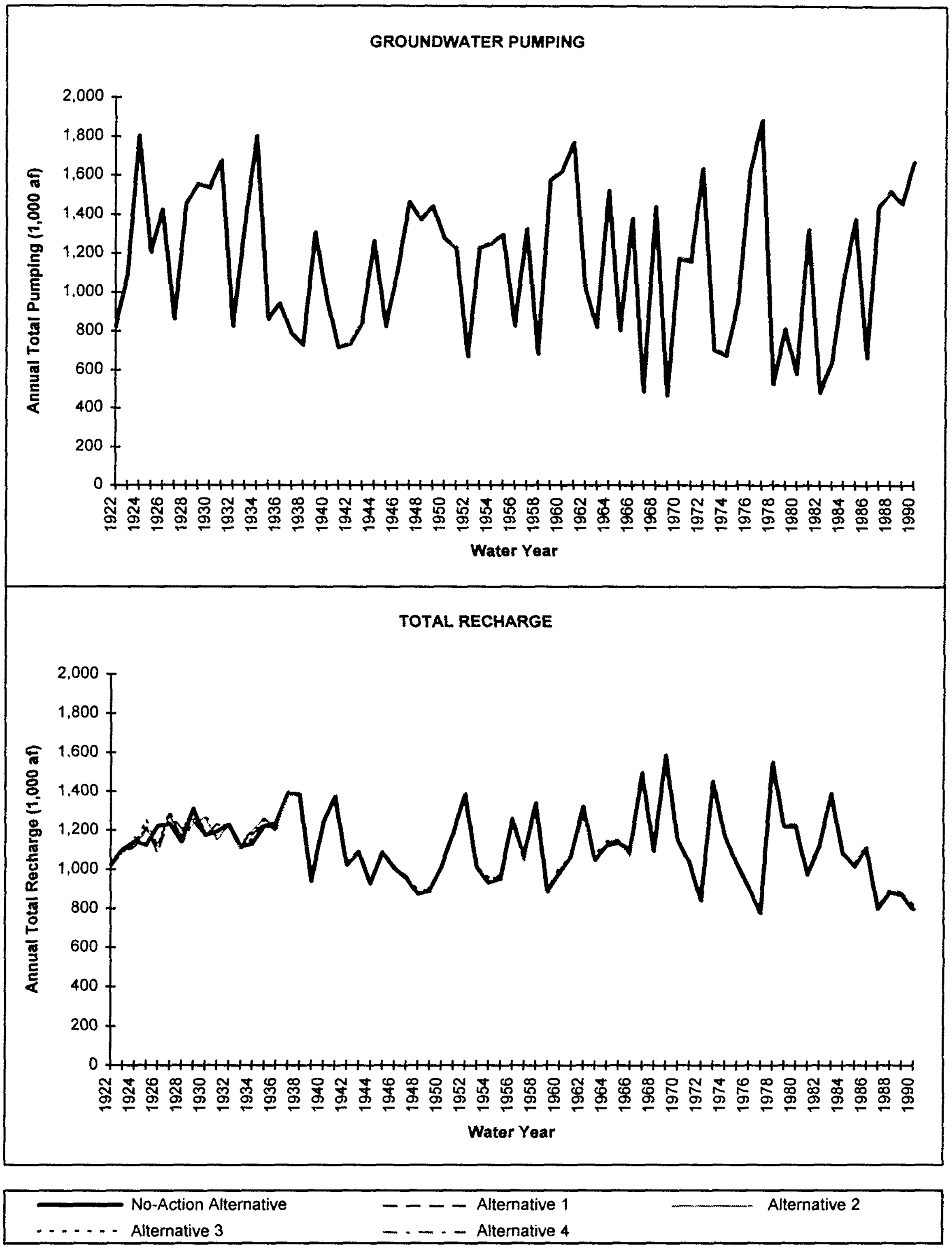

FIGURE B - 52
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 18

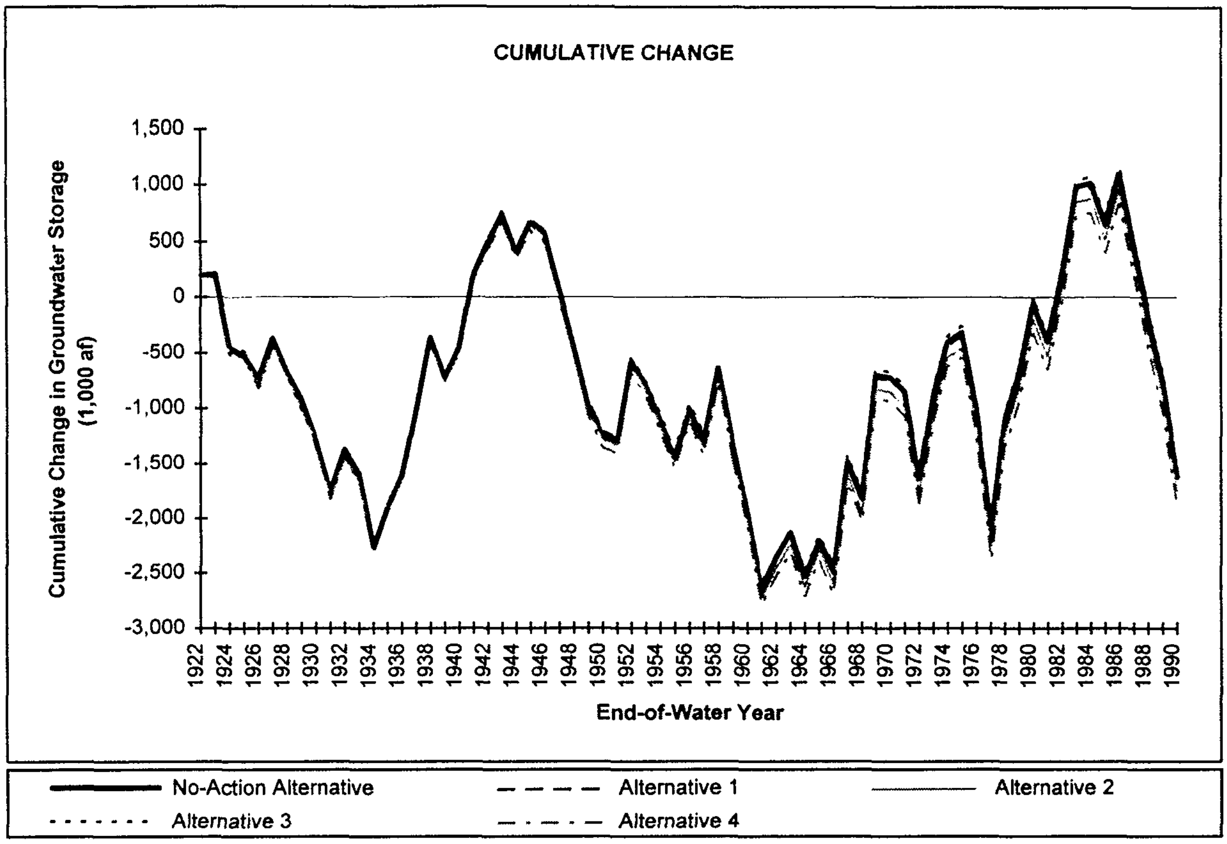

FIGURE B - 53
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 18

C—080618

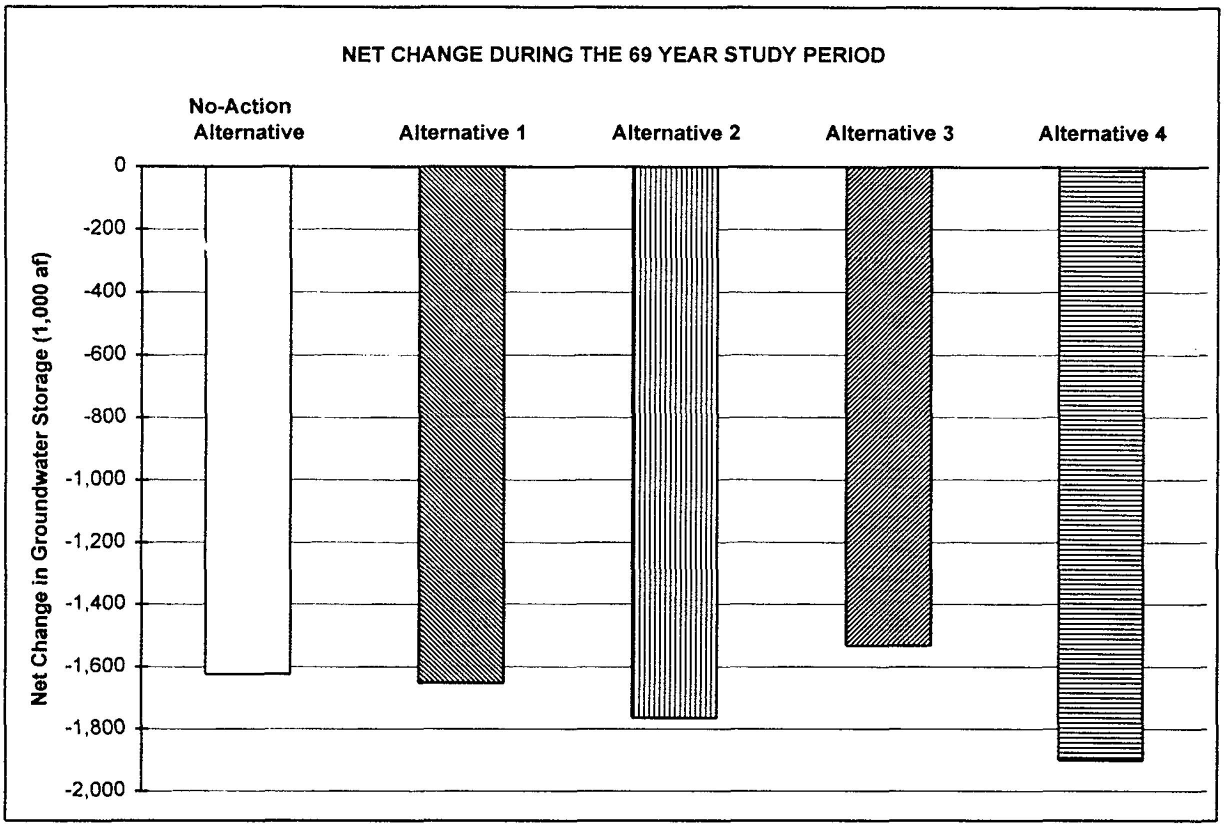

FIGURE B - 54
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 18

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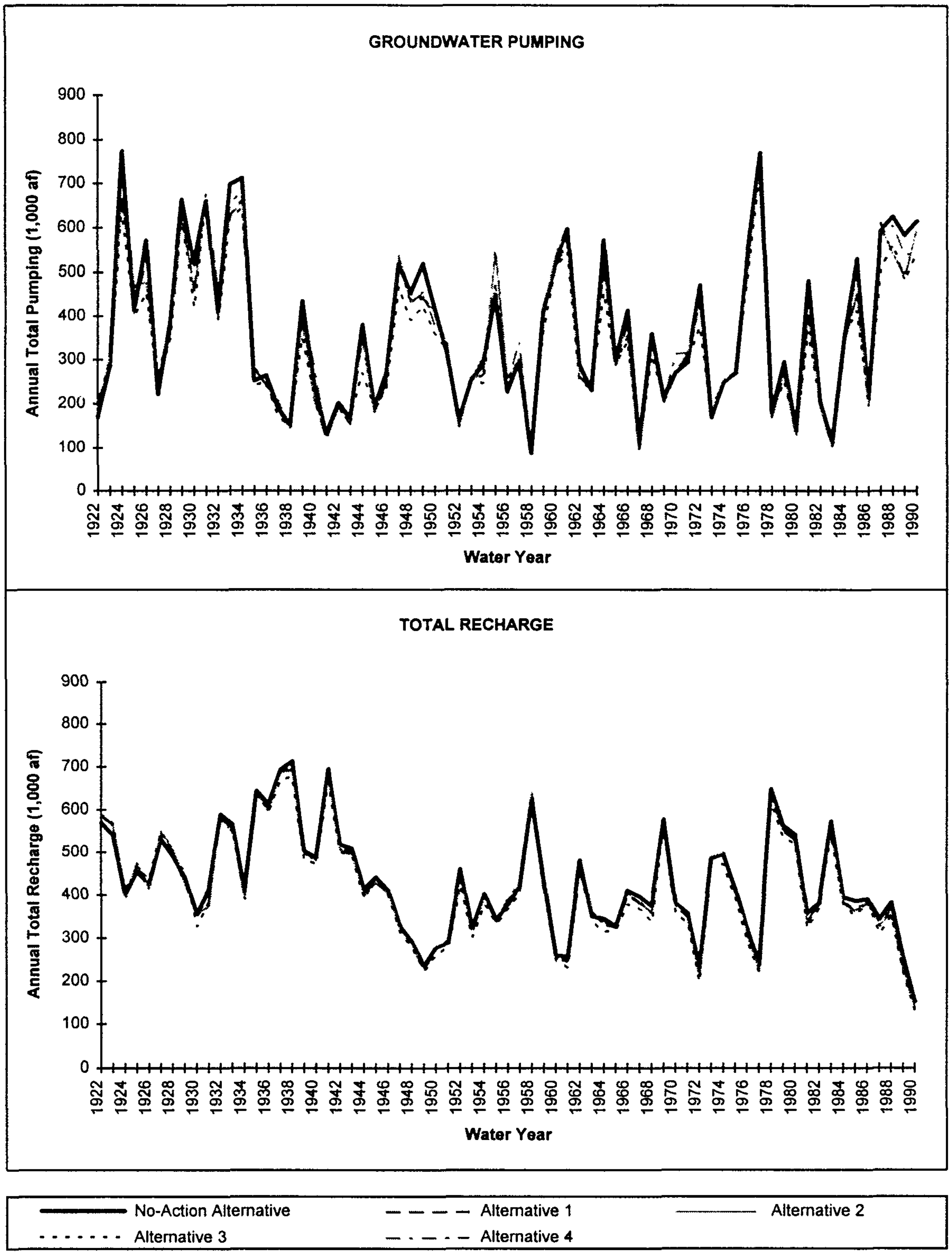

FIGURE B - 55
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 19

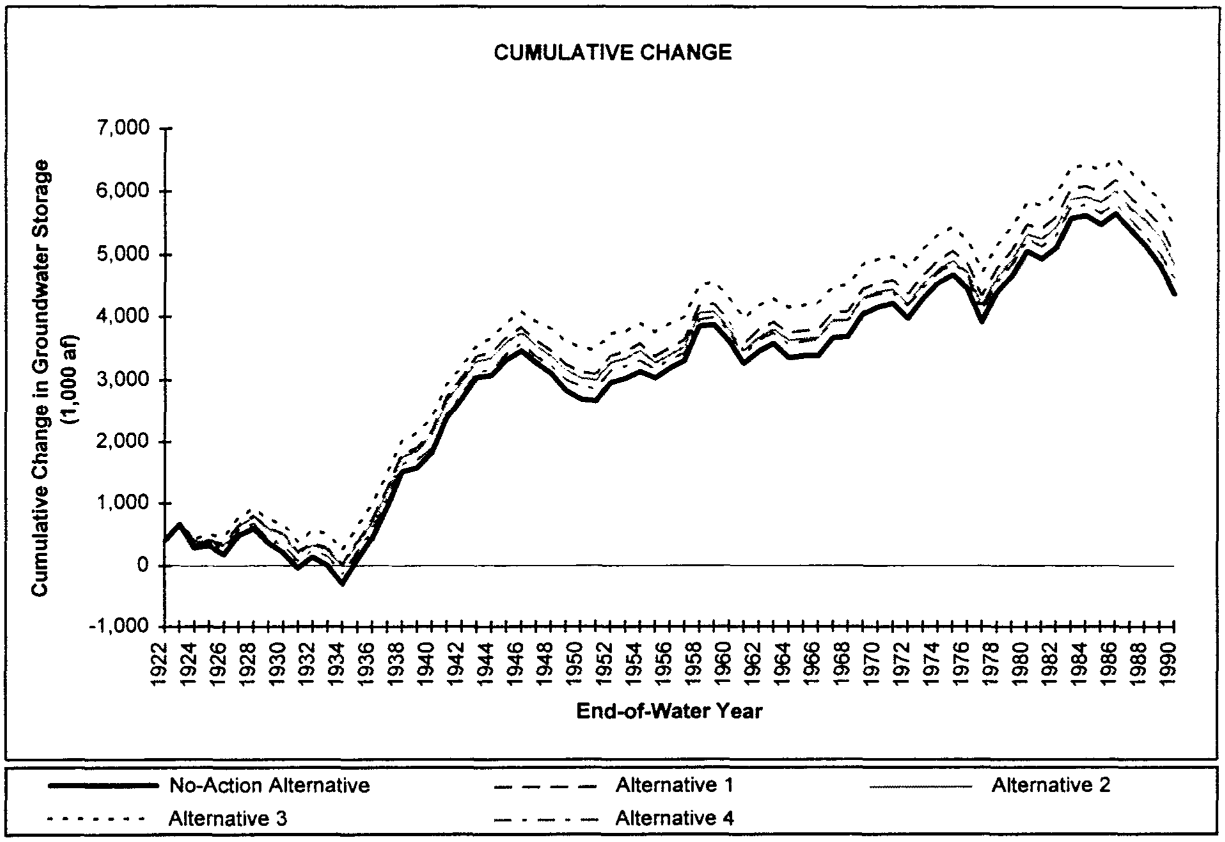

FIGURE B - 56
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 19

C—080622

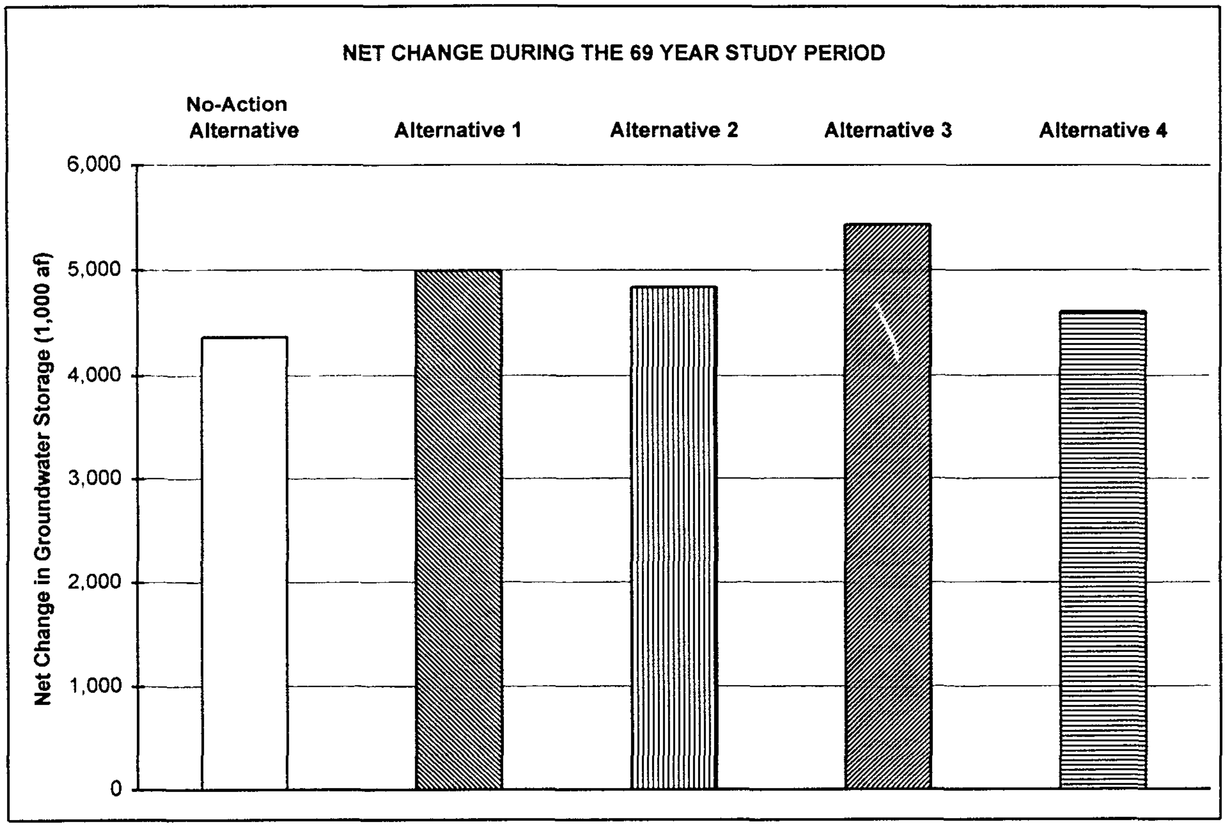

FIGURE B - 57
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 19

C—080623

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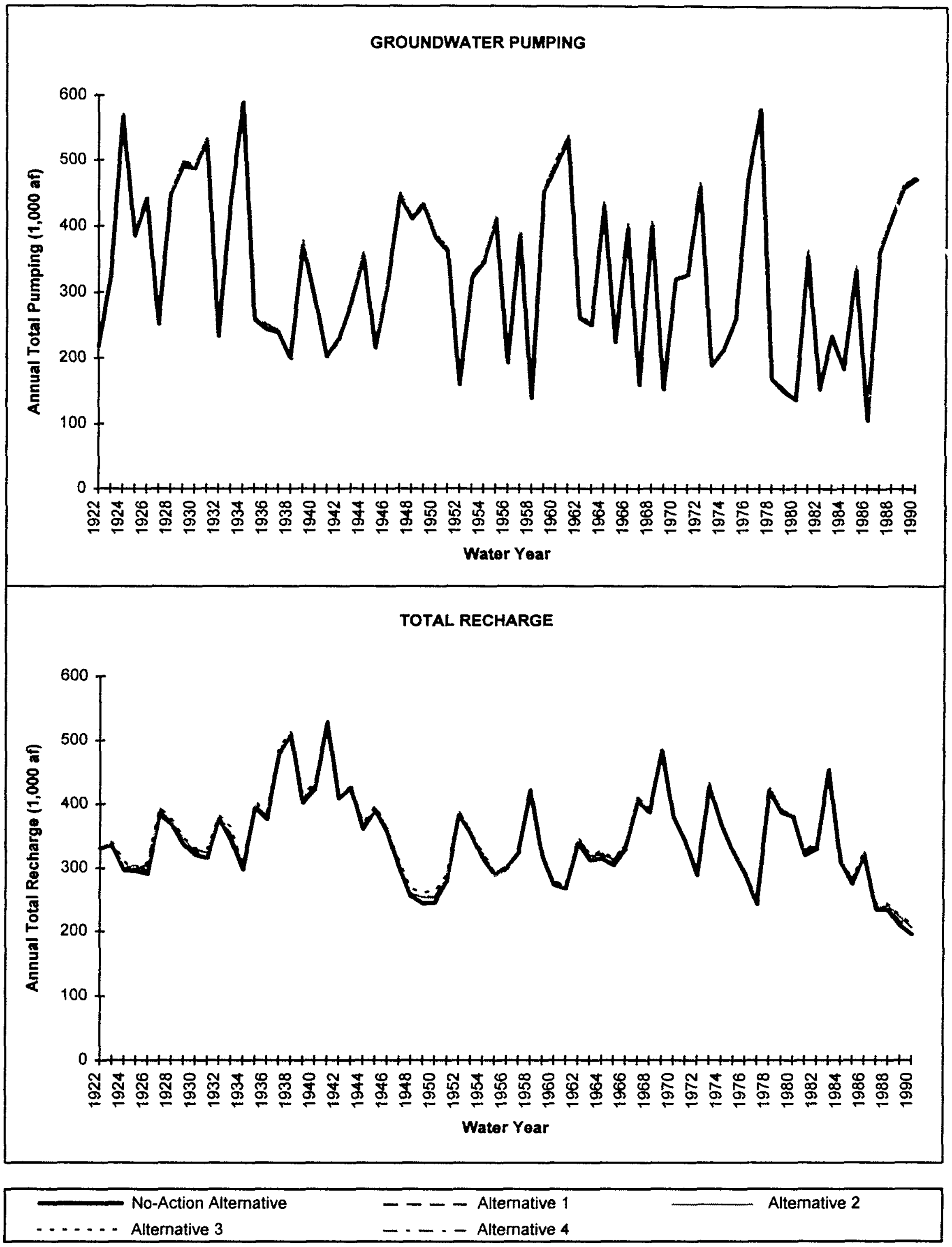

FIGURE B - 58
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 20

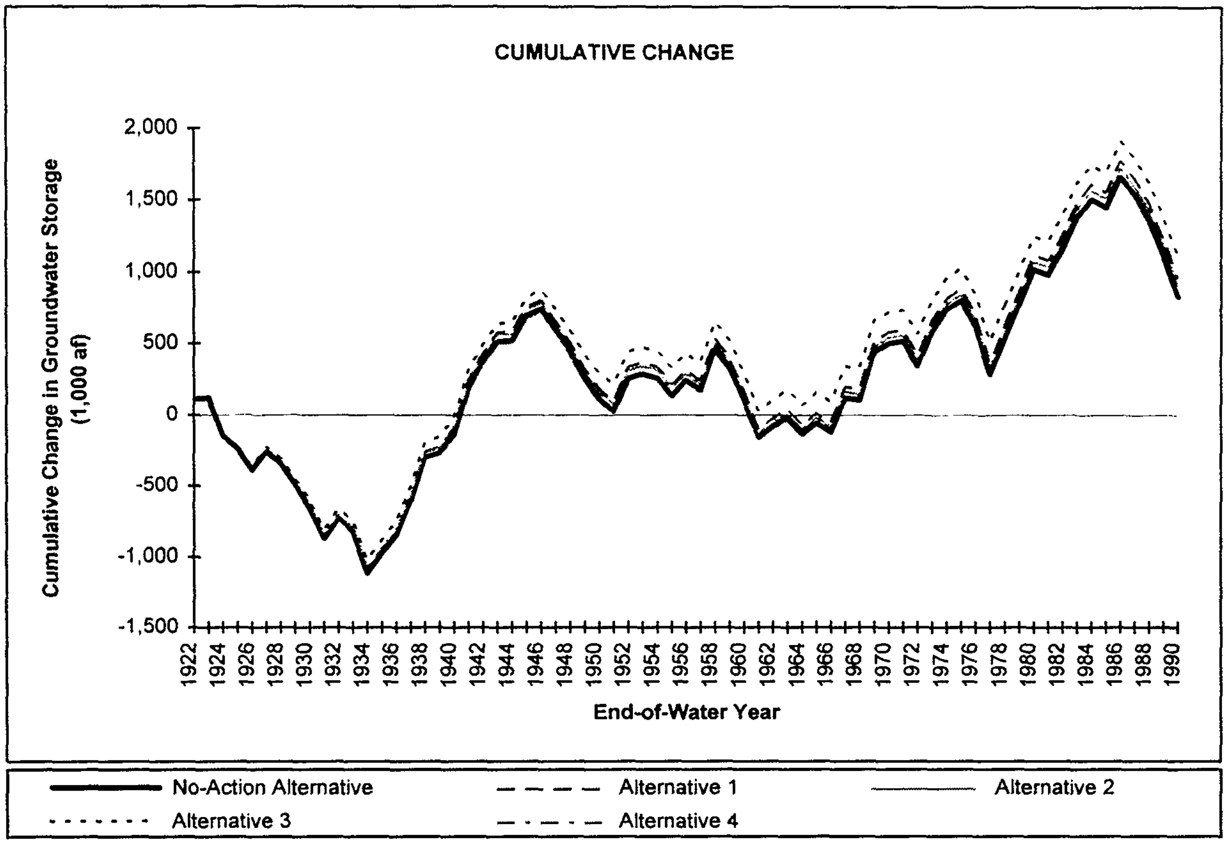

FIGURE B - 59
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 20

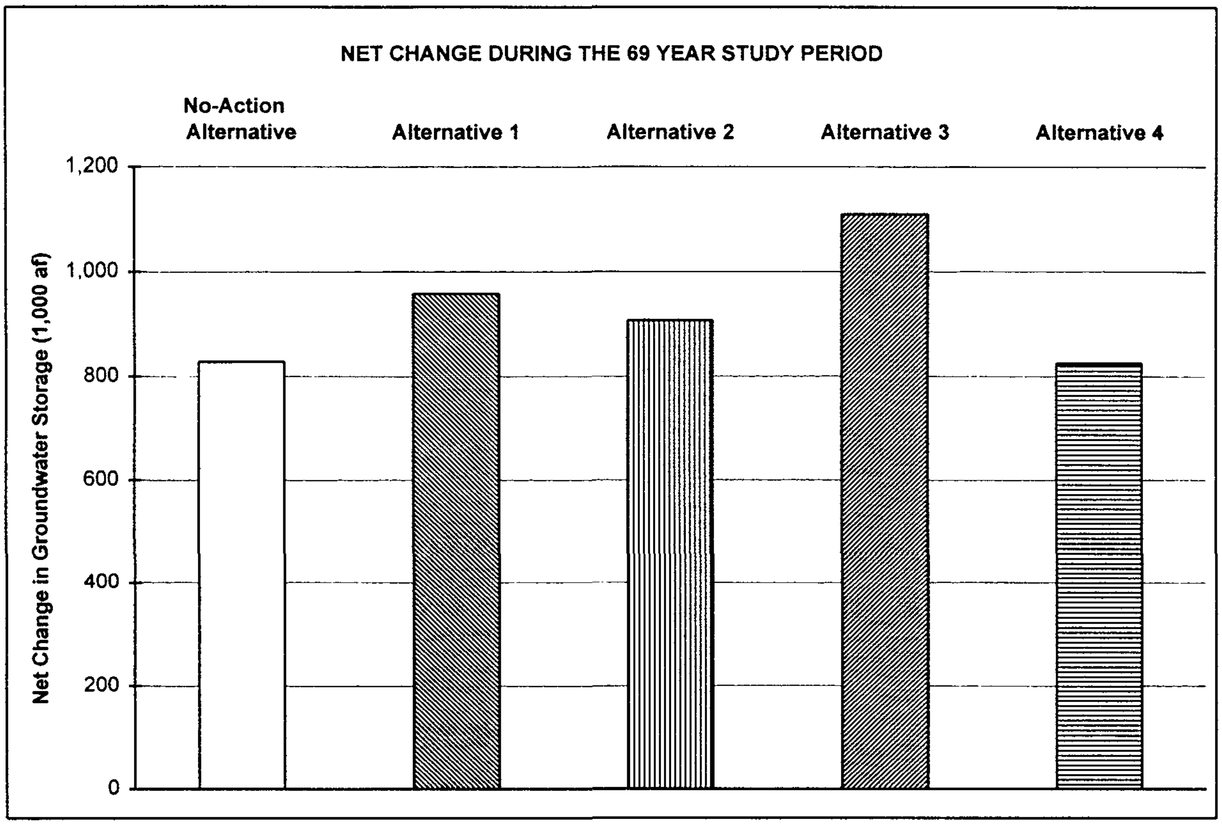

FIGURE B - 60
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 20

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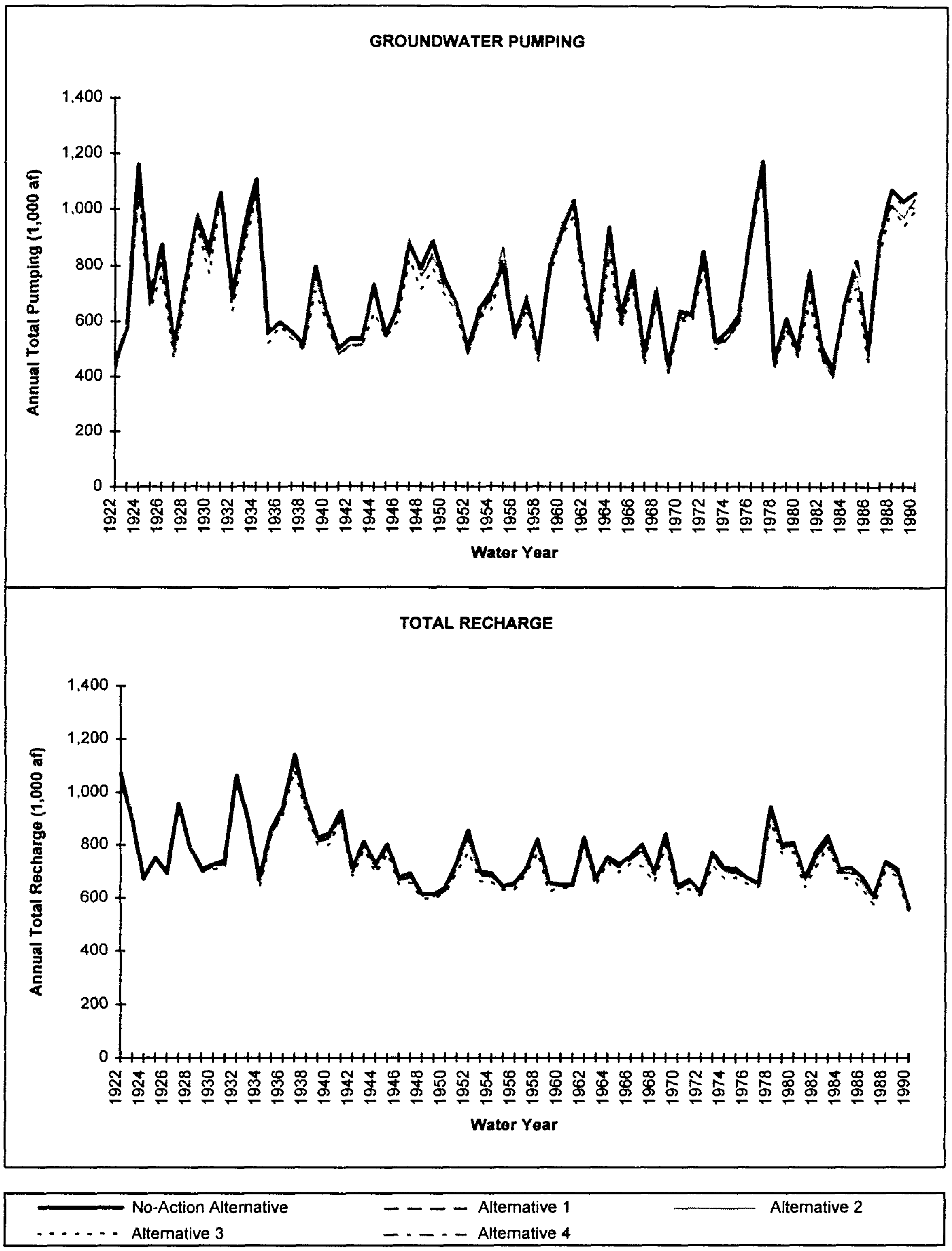

FIGURE B - 61
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 21

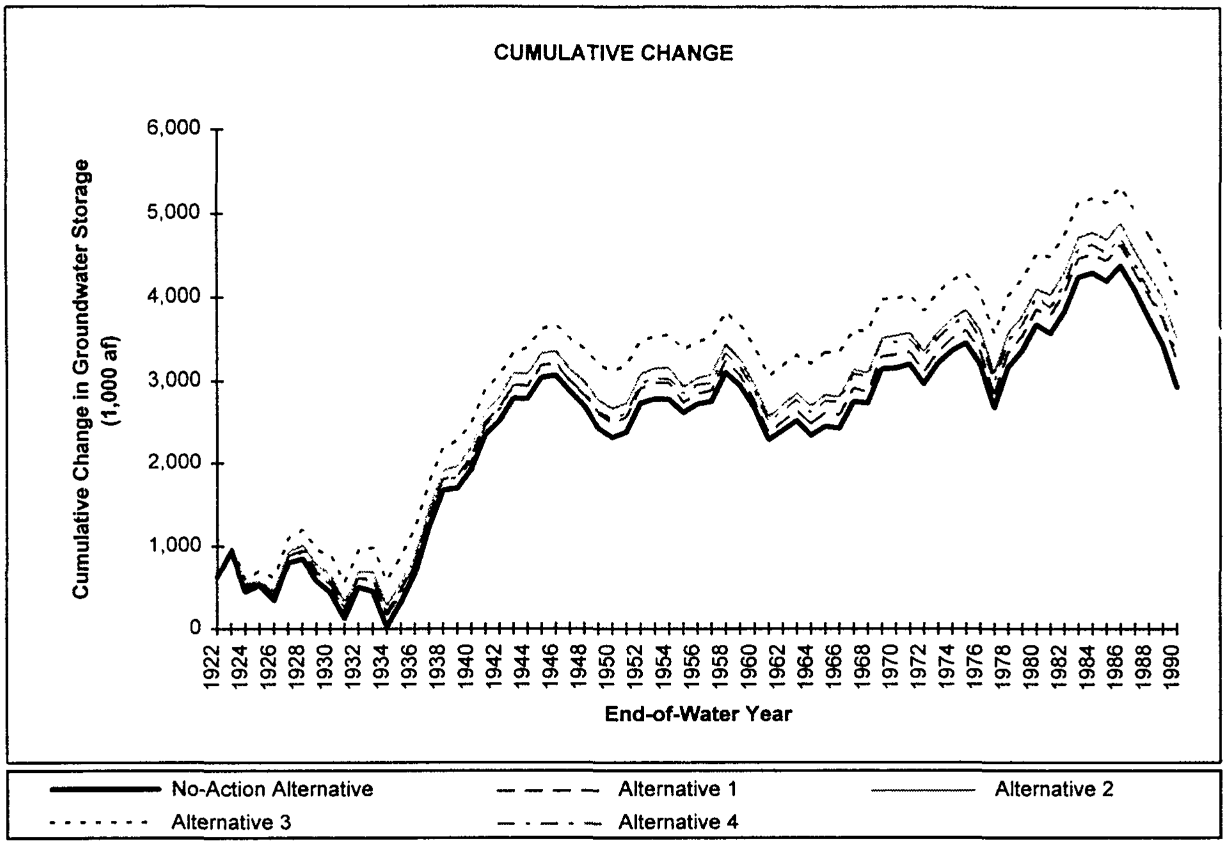

FIGURE B - 62
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 21

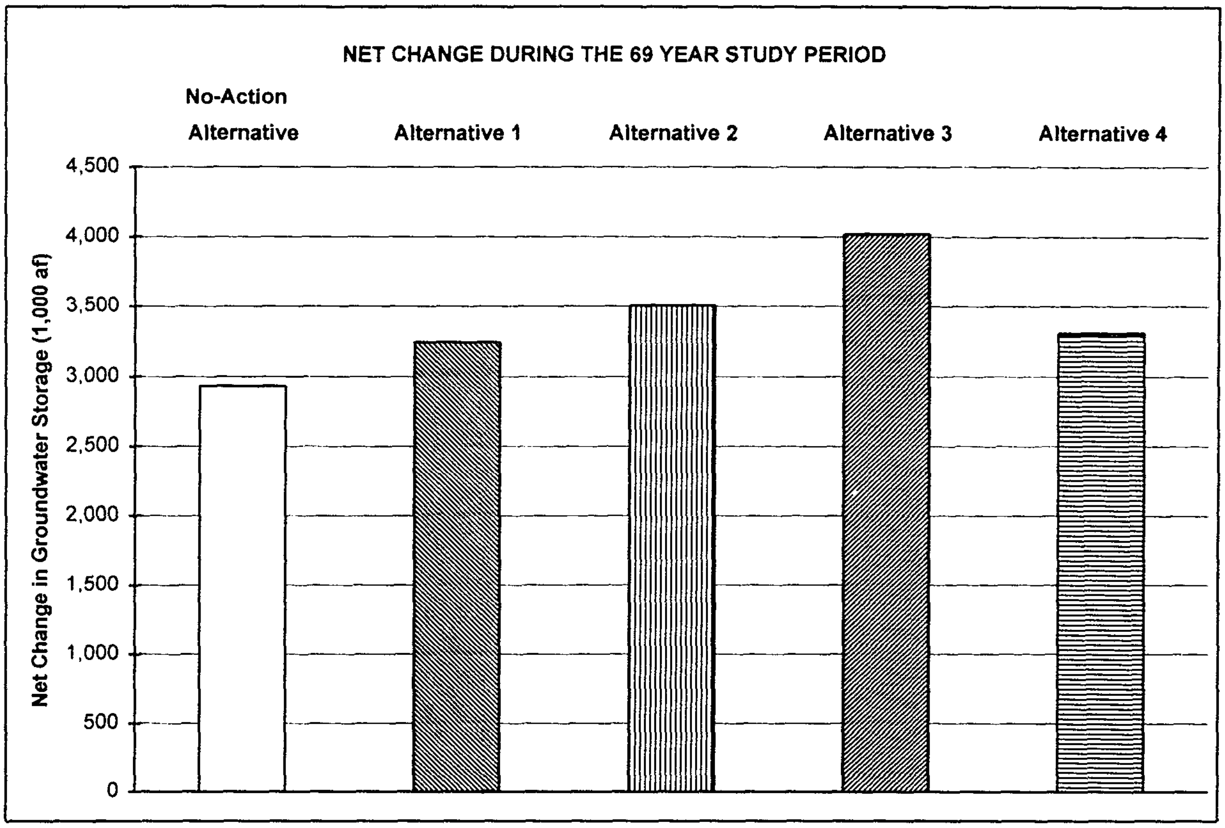

FIGURE B - 63
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 21

C—080631

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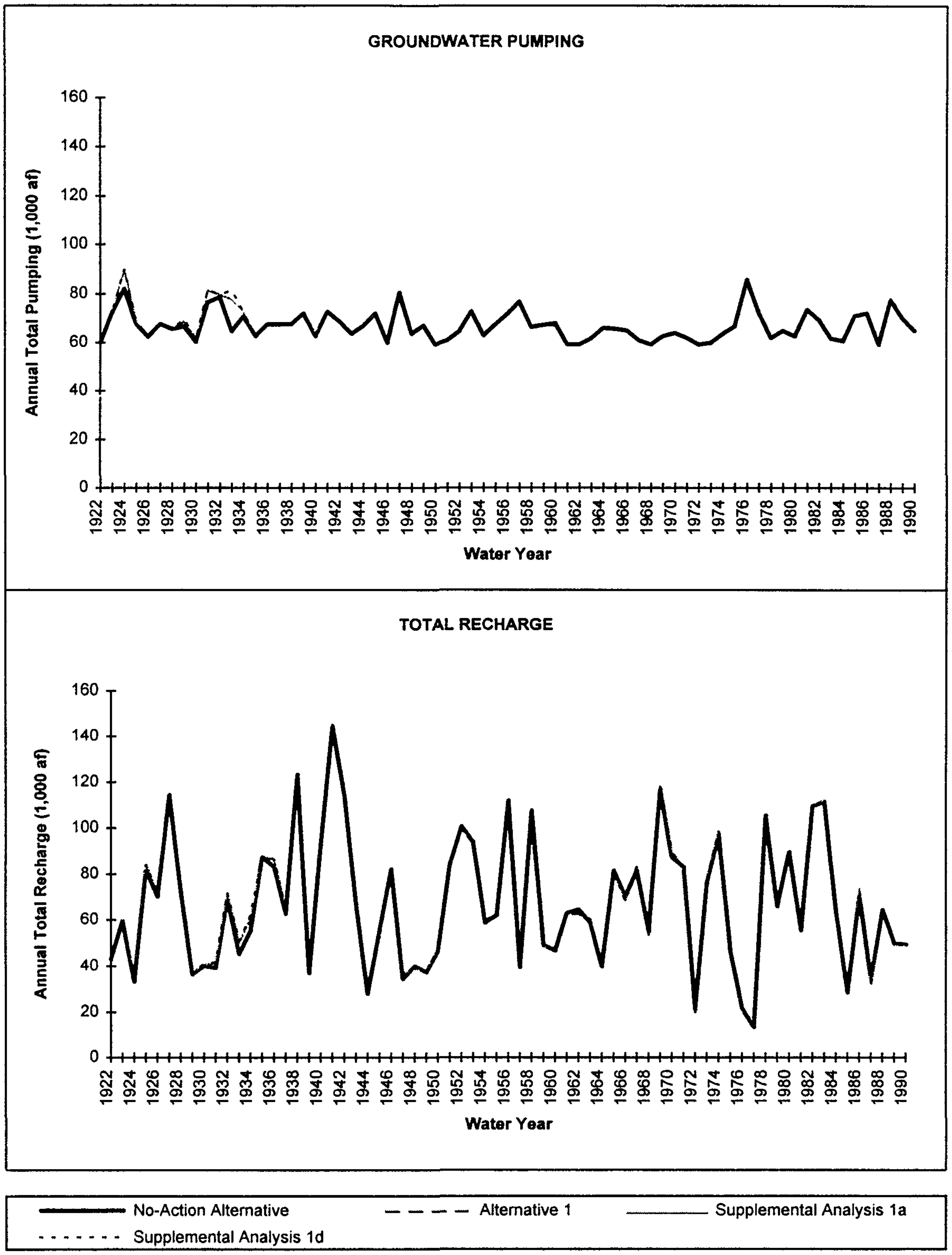

FIGURE B - 64
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 1

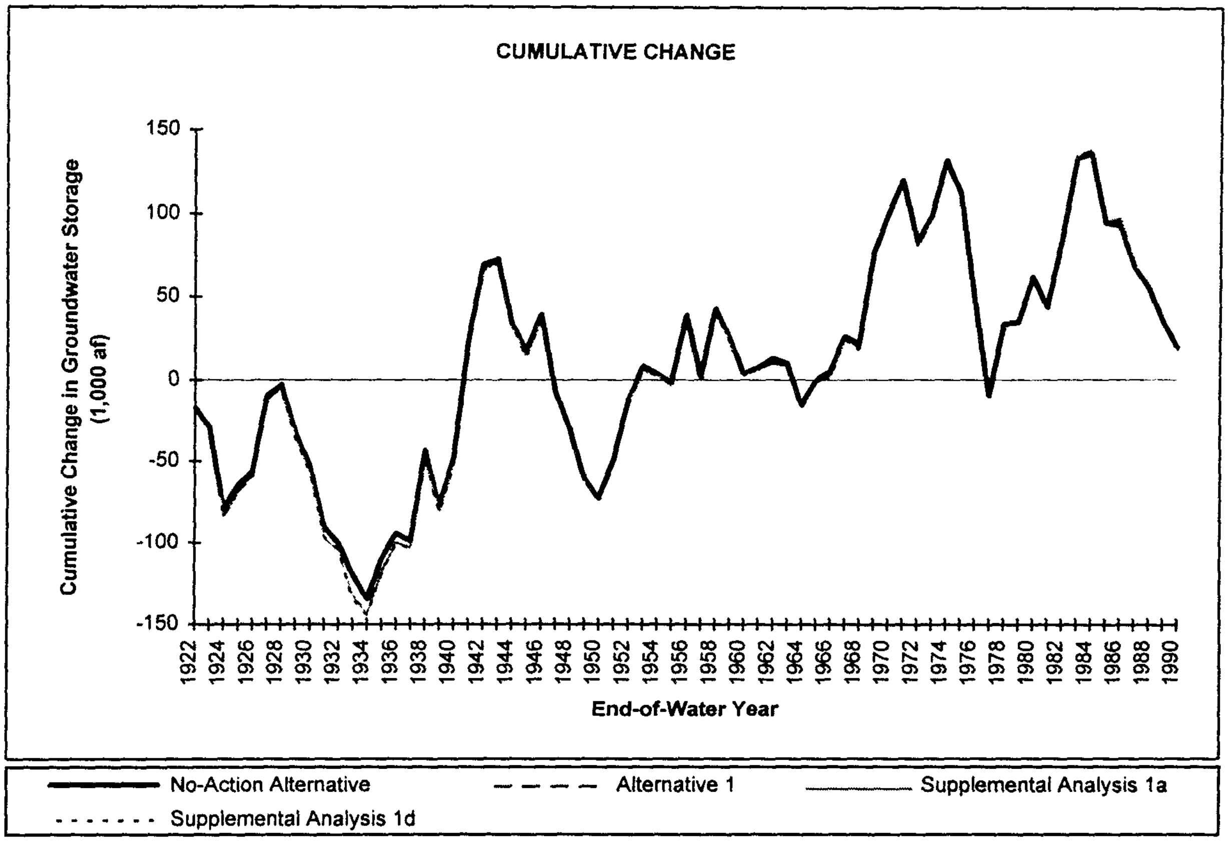

FIGURE B - 65
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 1

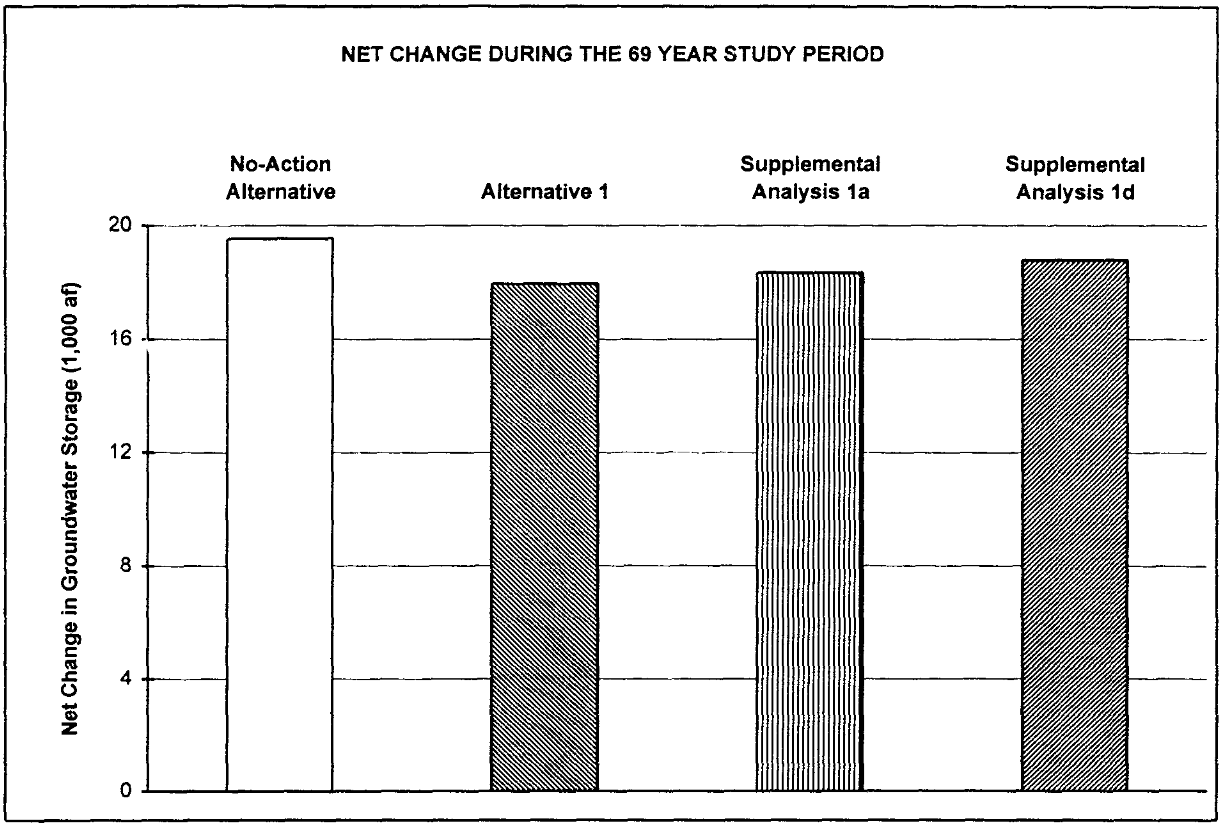

FIGURE B - 66
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 1

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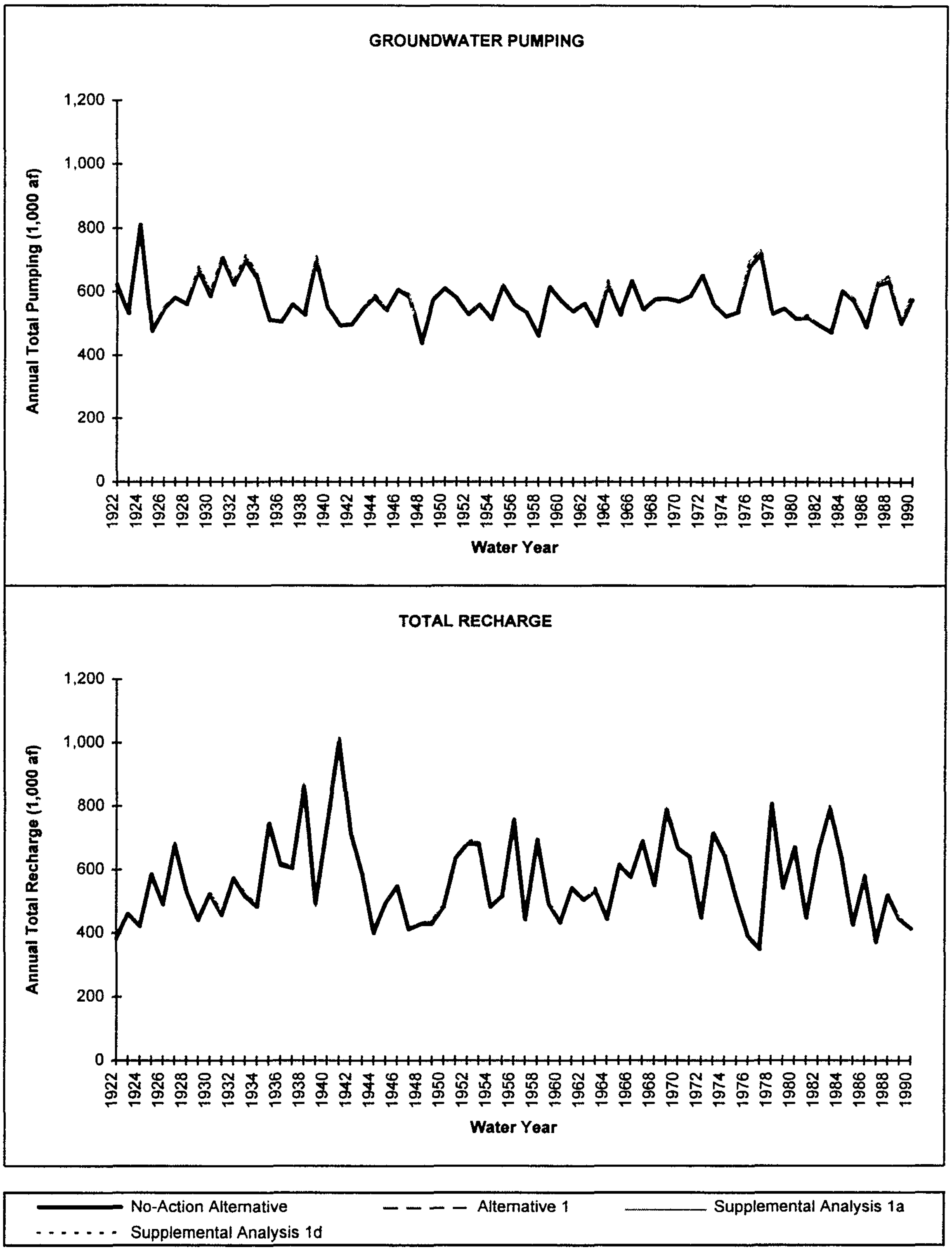

FIGURE B - 67
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 2

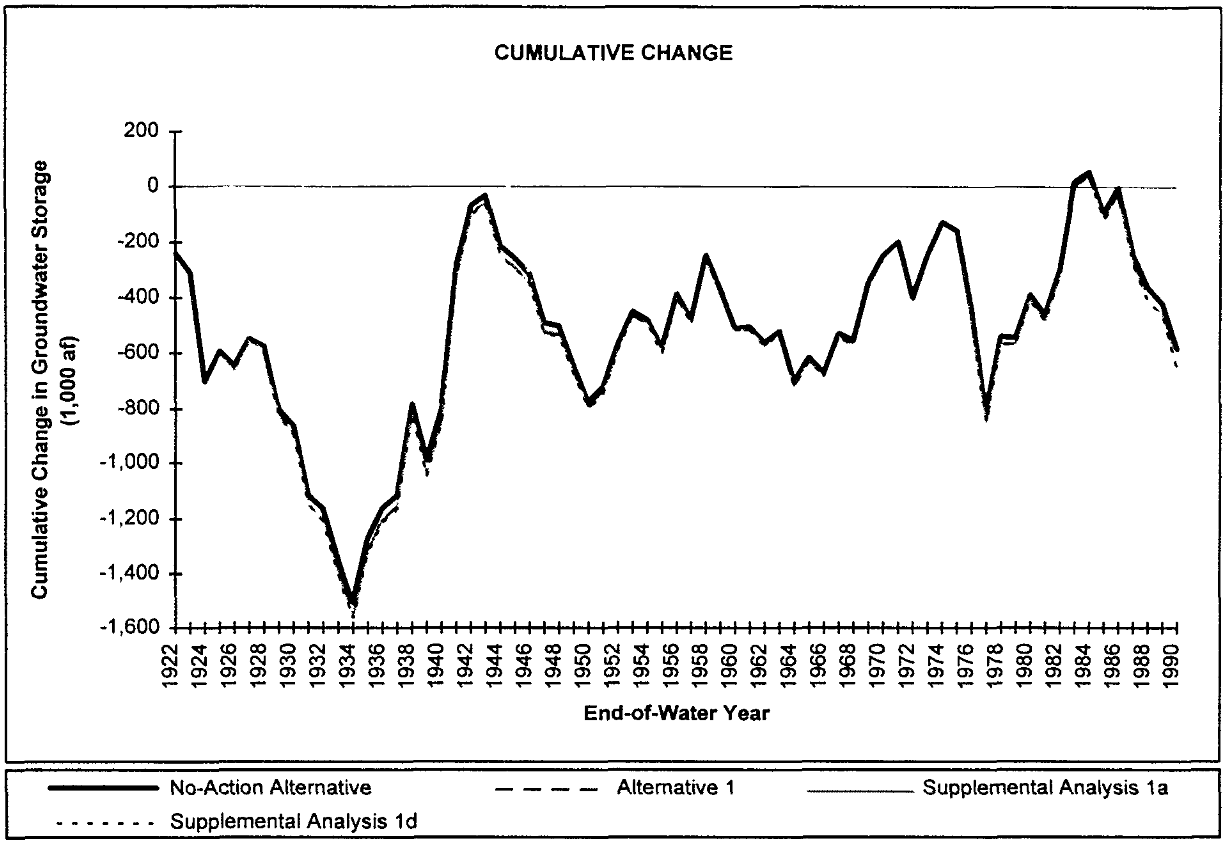

FIGURE B - 68
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 2

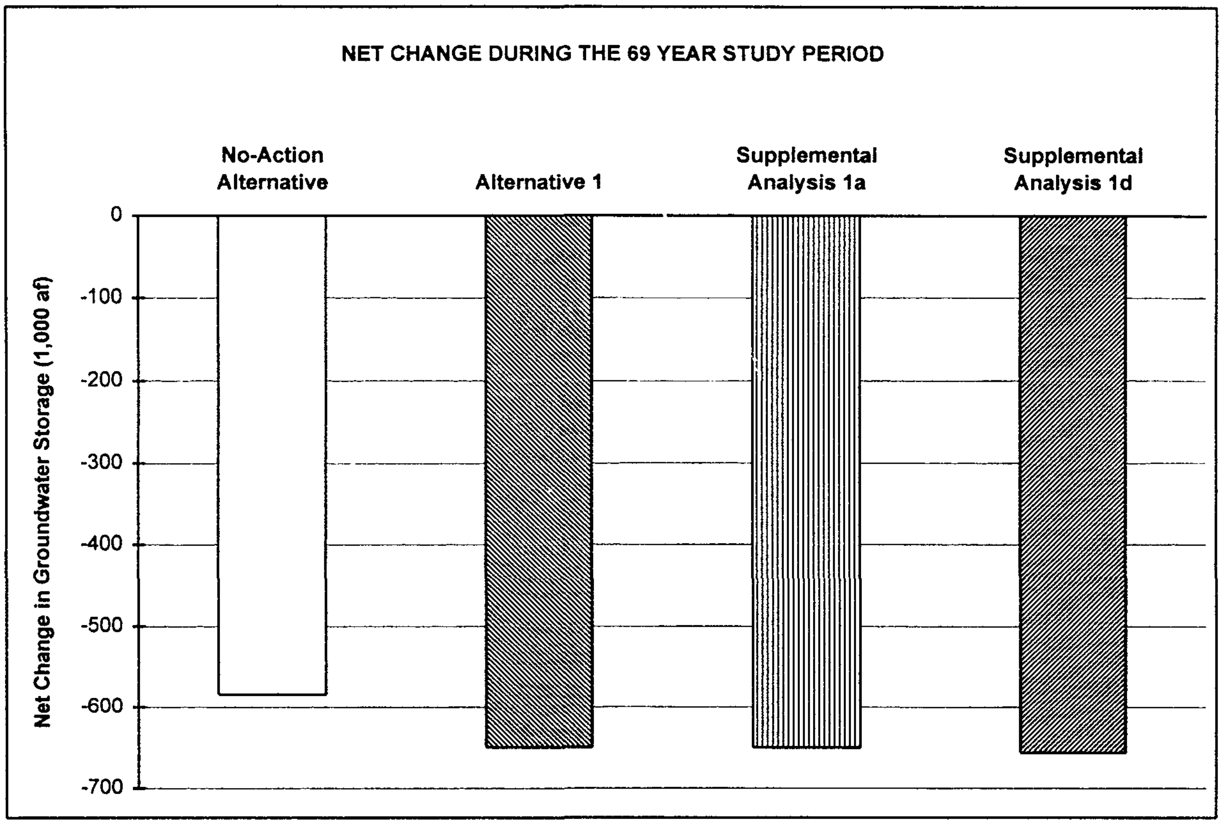

FIGURE B - 69
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 2

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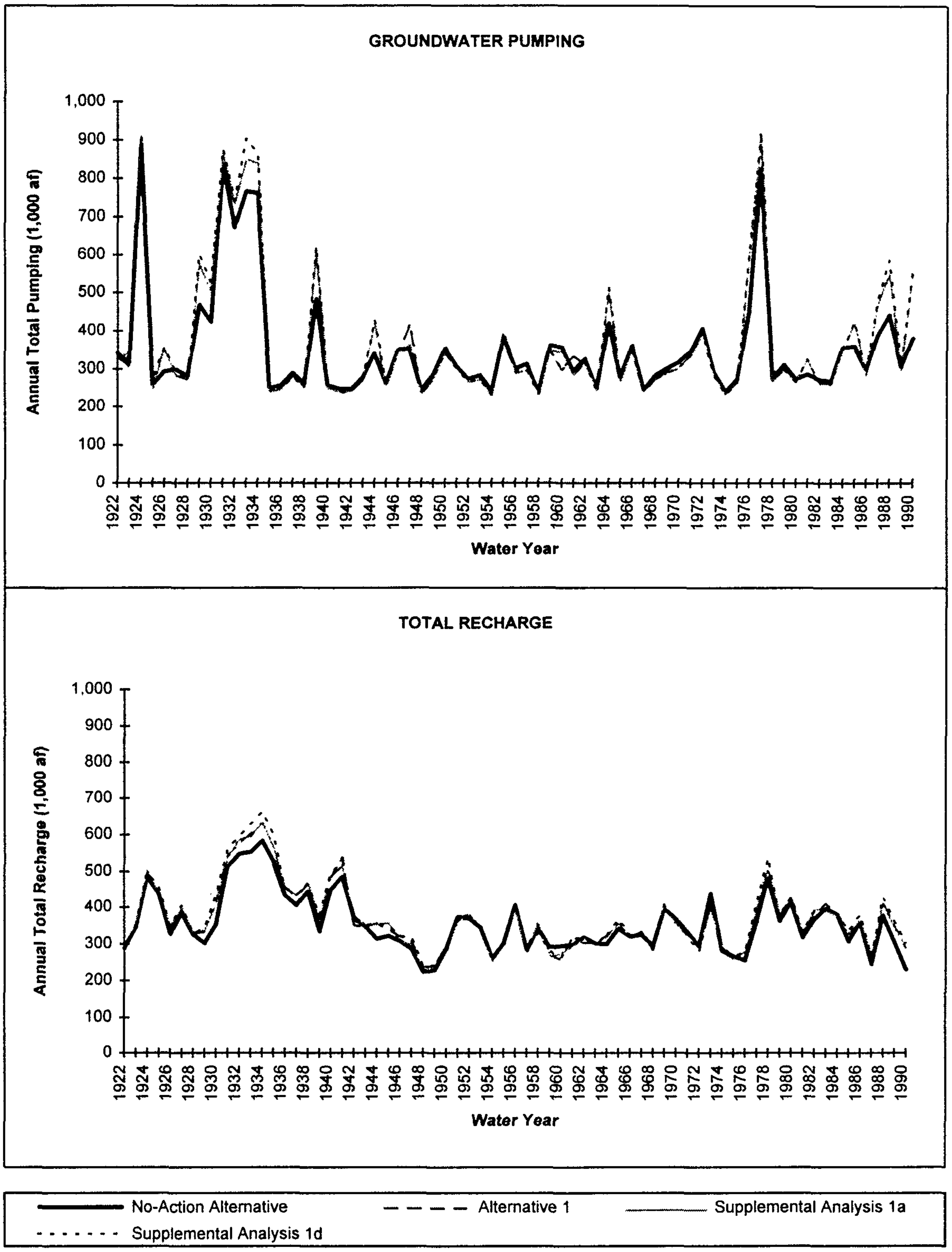

FIGURE B - 70
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 3

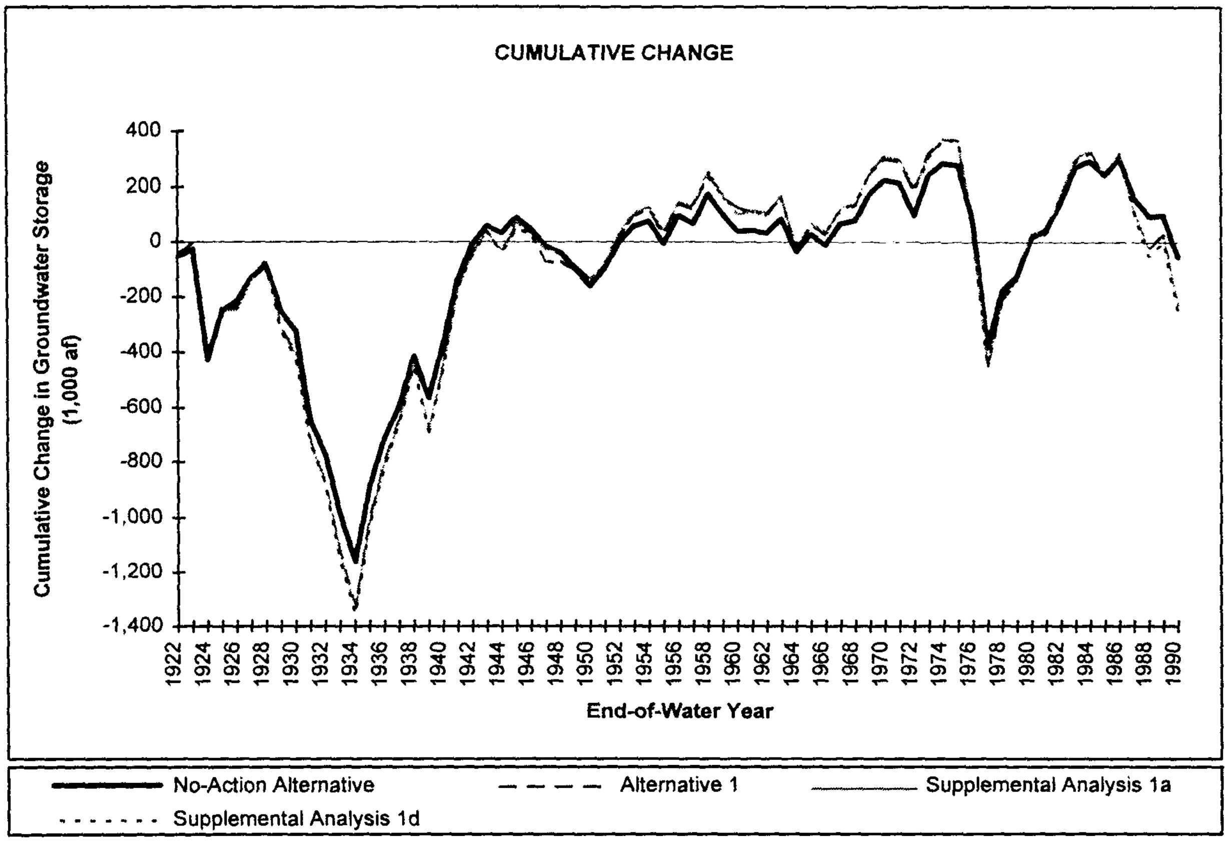

FIGURE B - 71
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 3

C—080642

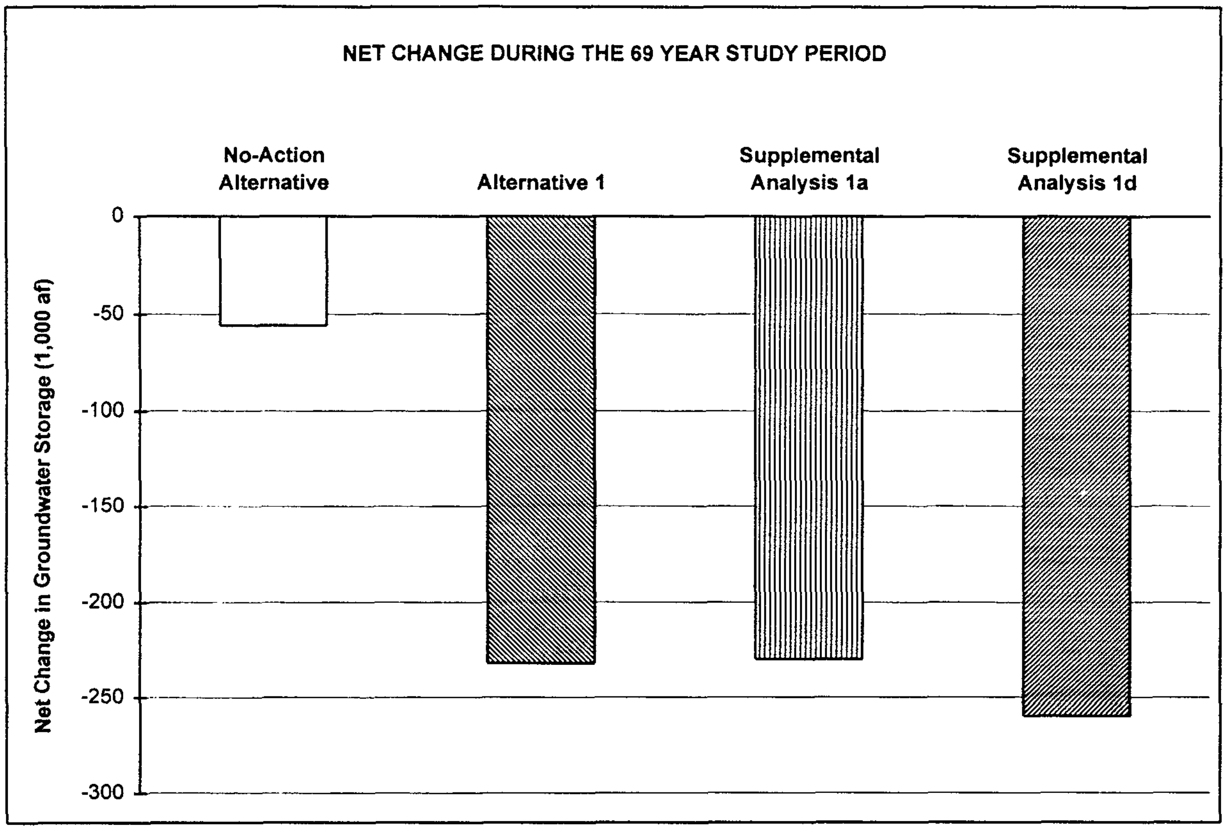

FIGURE B - 72
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 3

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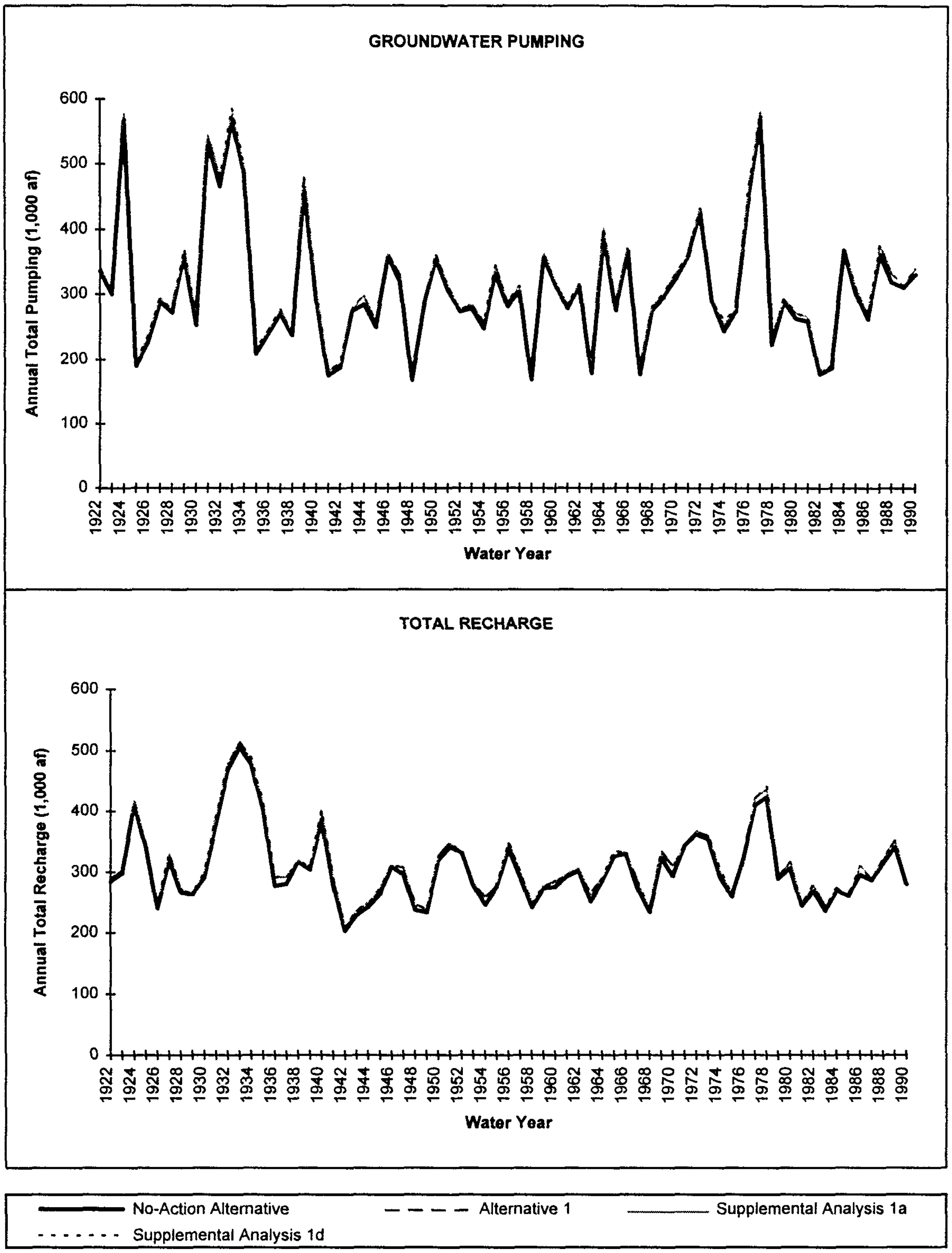

FIGURE B - 73
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 4

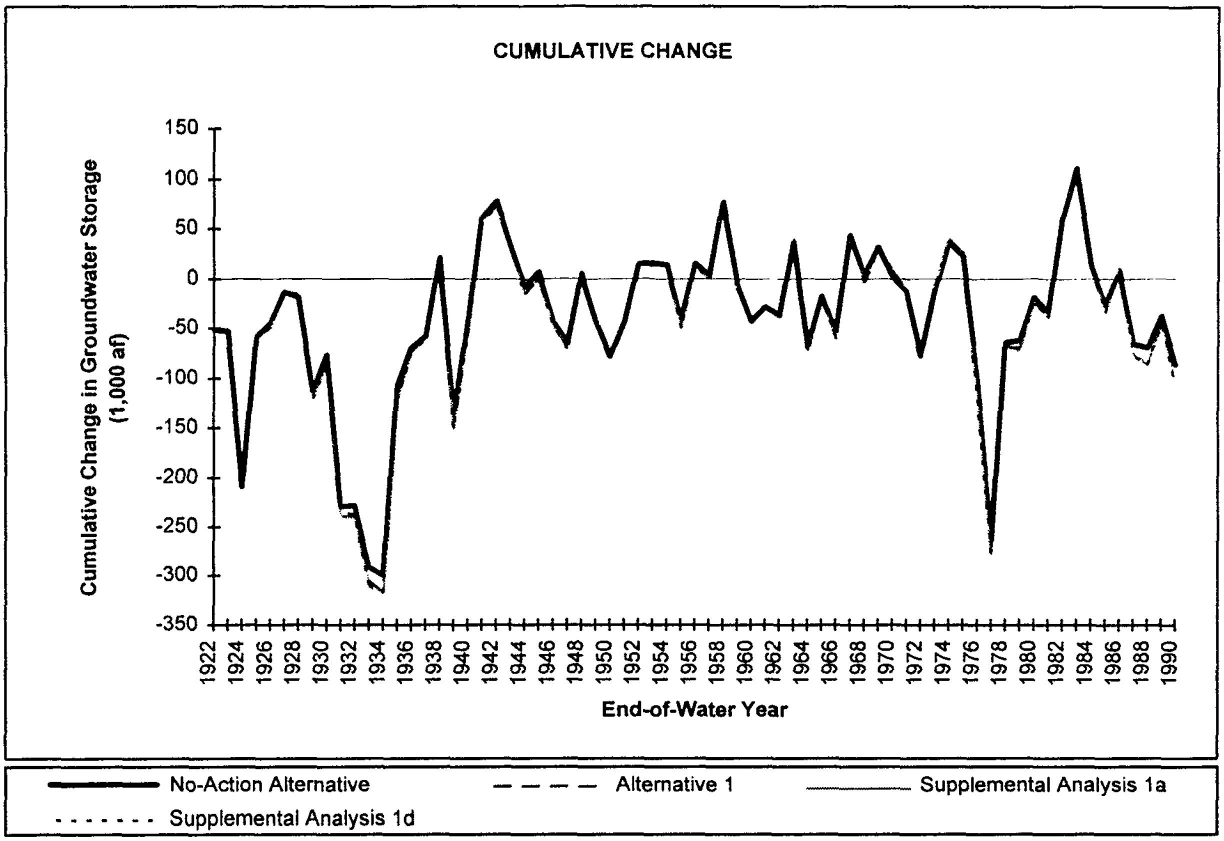

FIGURE B - 74
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 4

C—080646

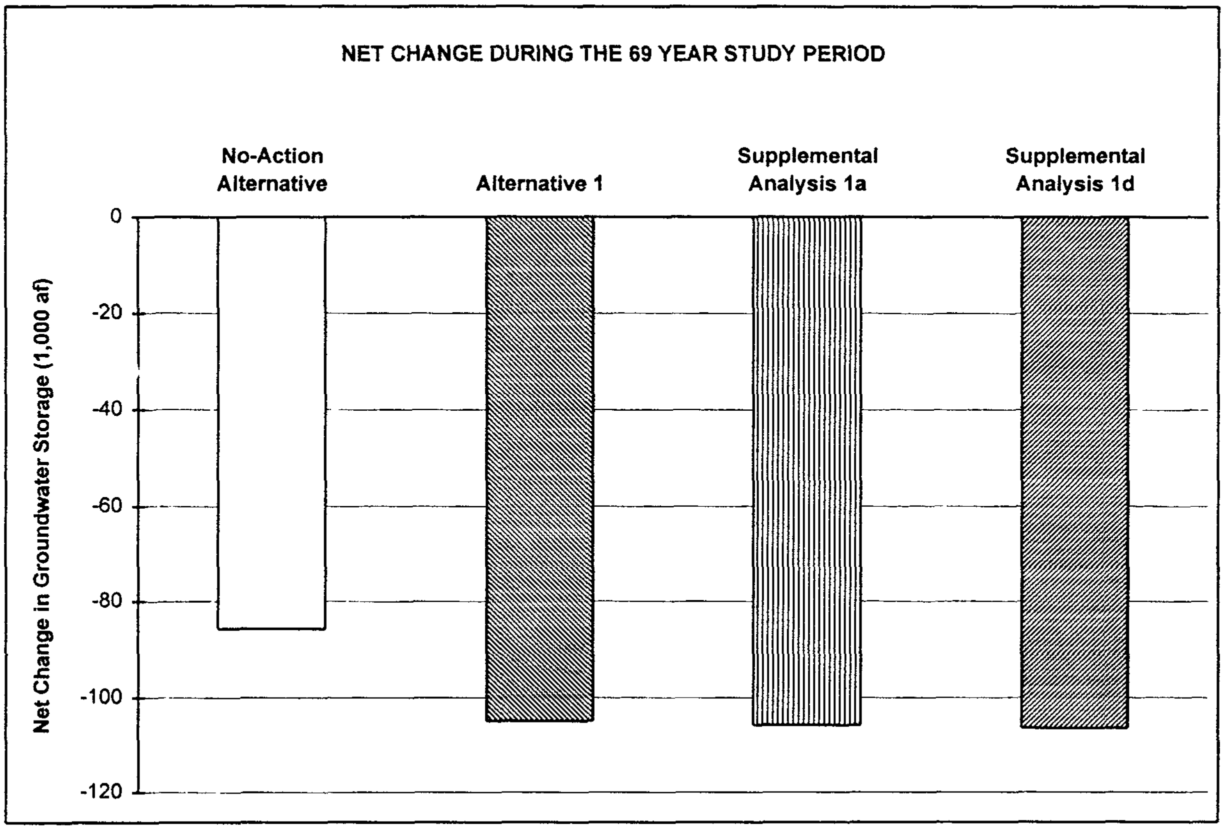

FIGURE B - 75
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 4

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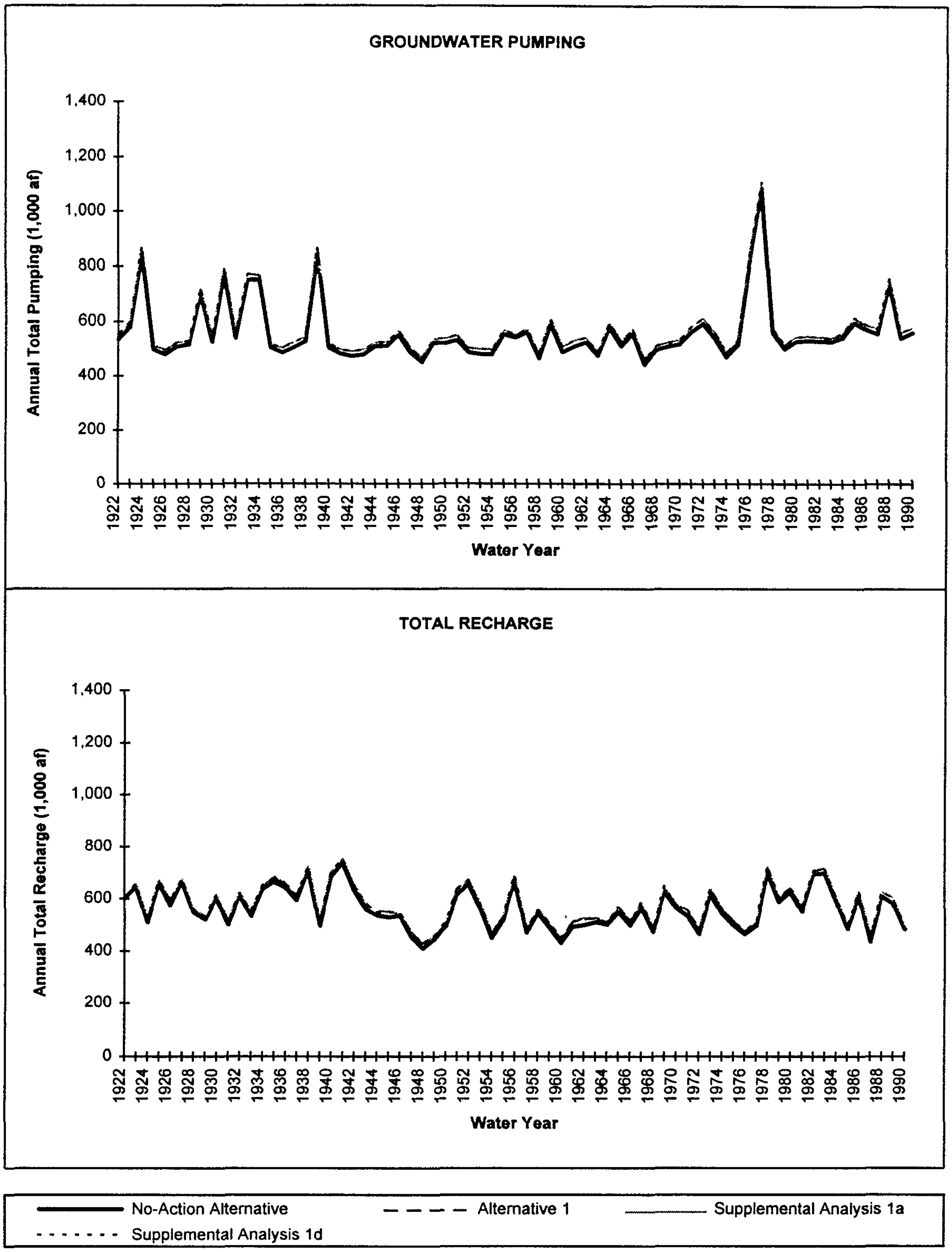

FIGURE B - 76
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 5

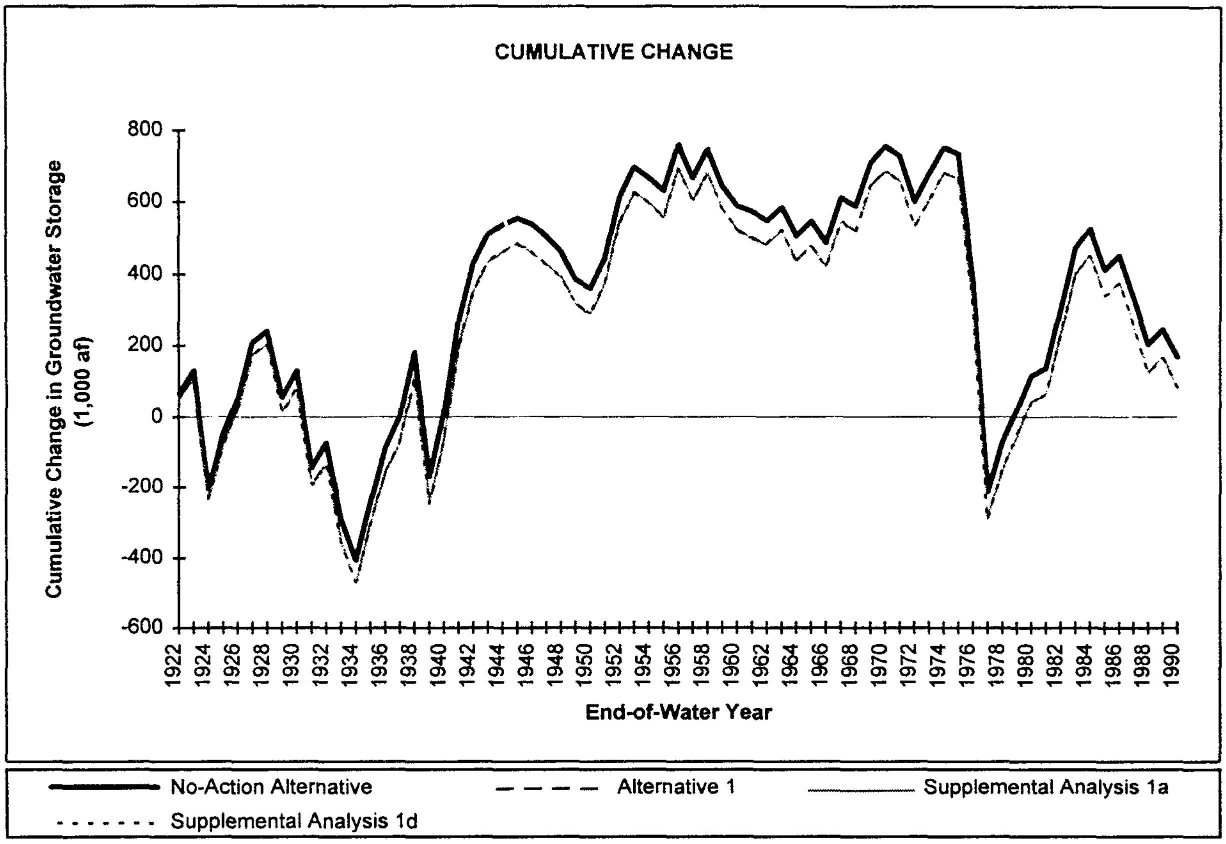

FIGURE B - 77
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 5

C-080650

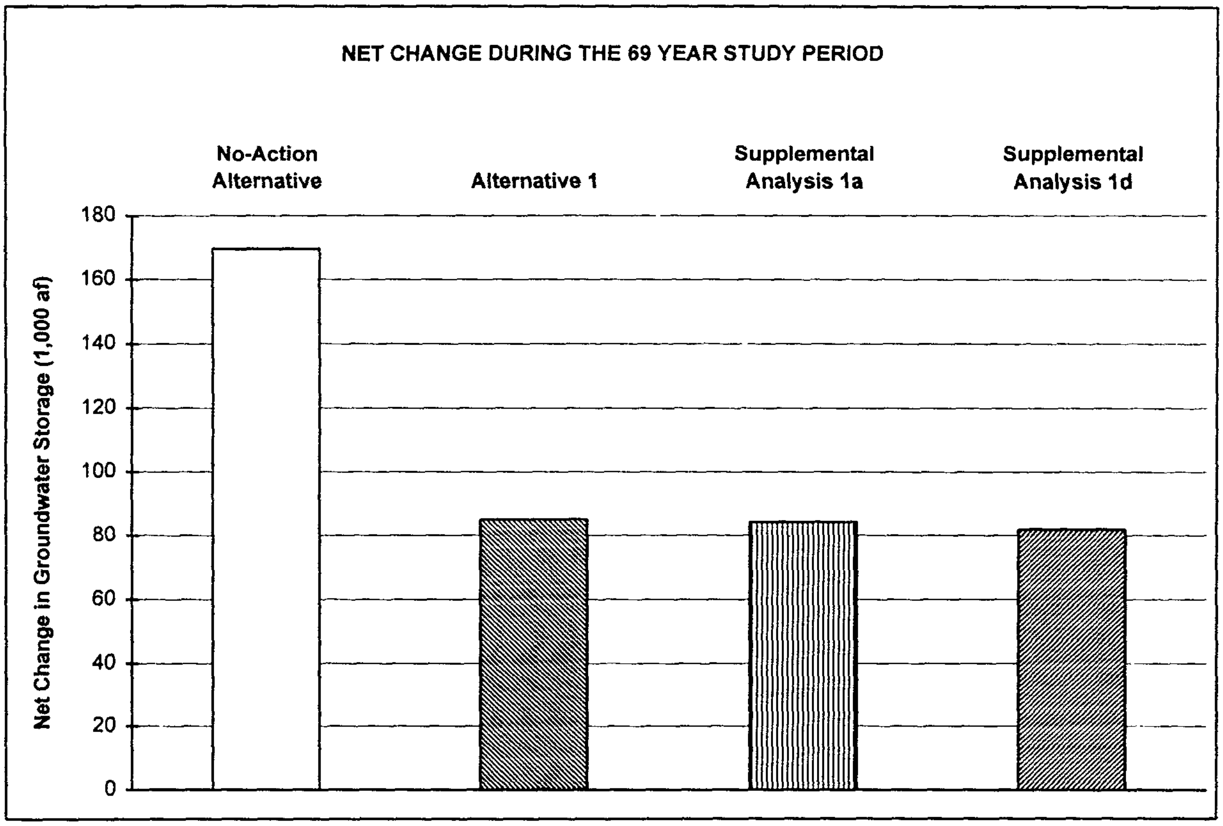

FIGURE B - 78
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 5

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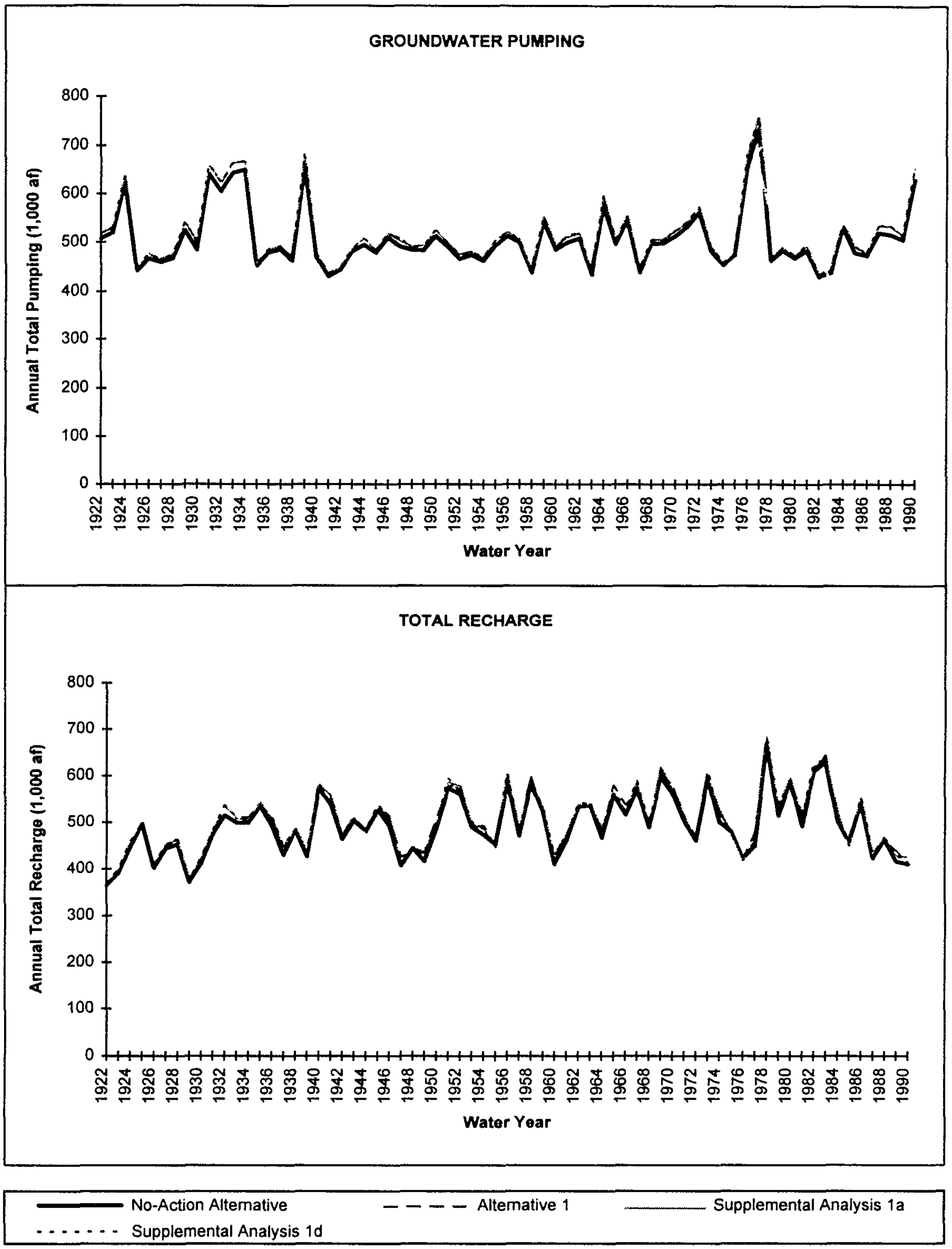

FIGURE B - 79
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 6

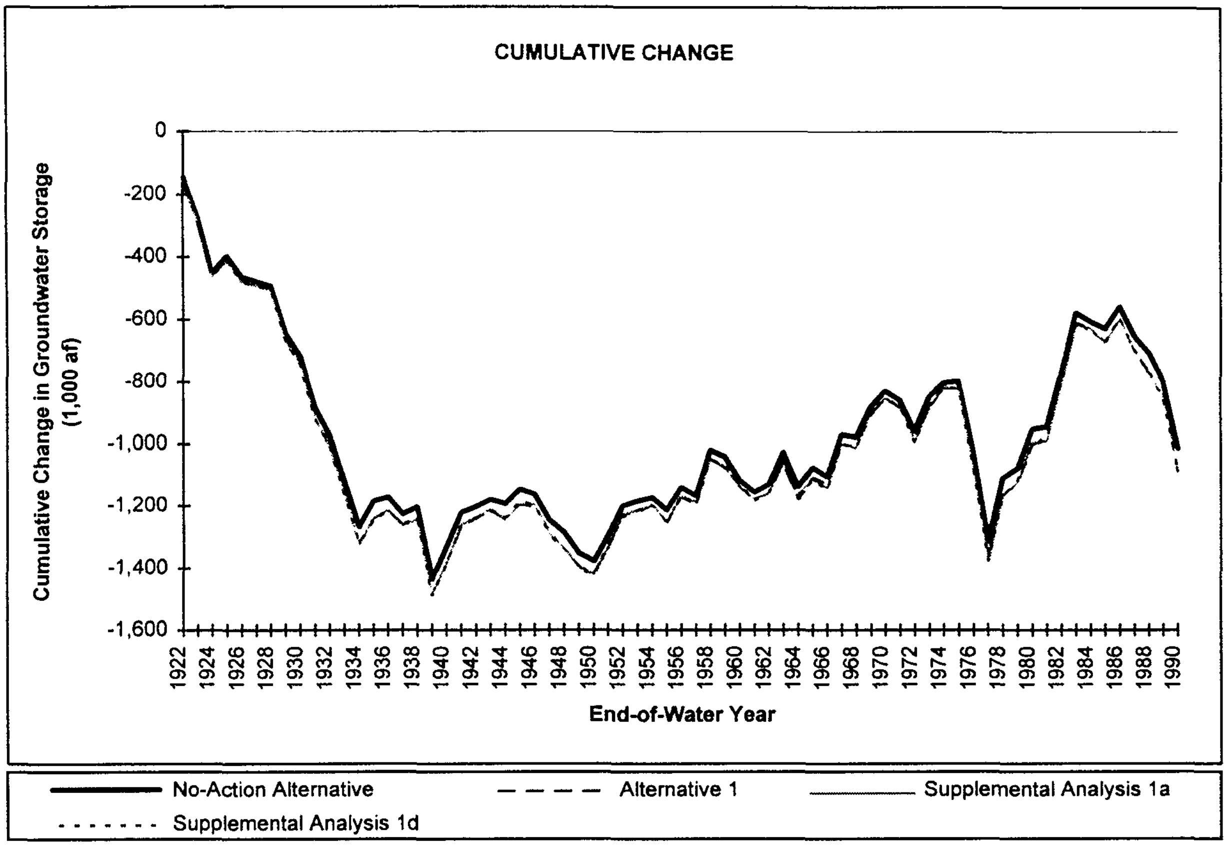

FIGURE B - 80
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 6

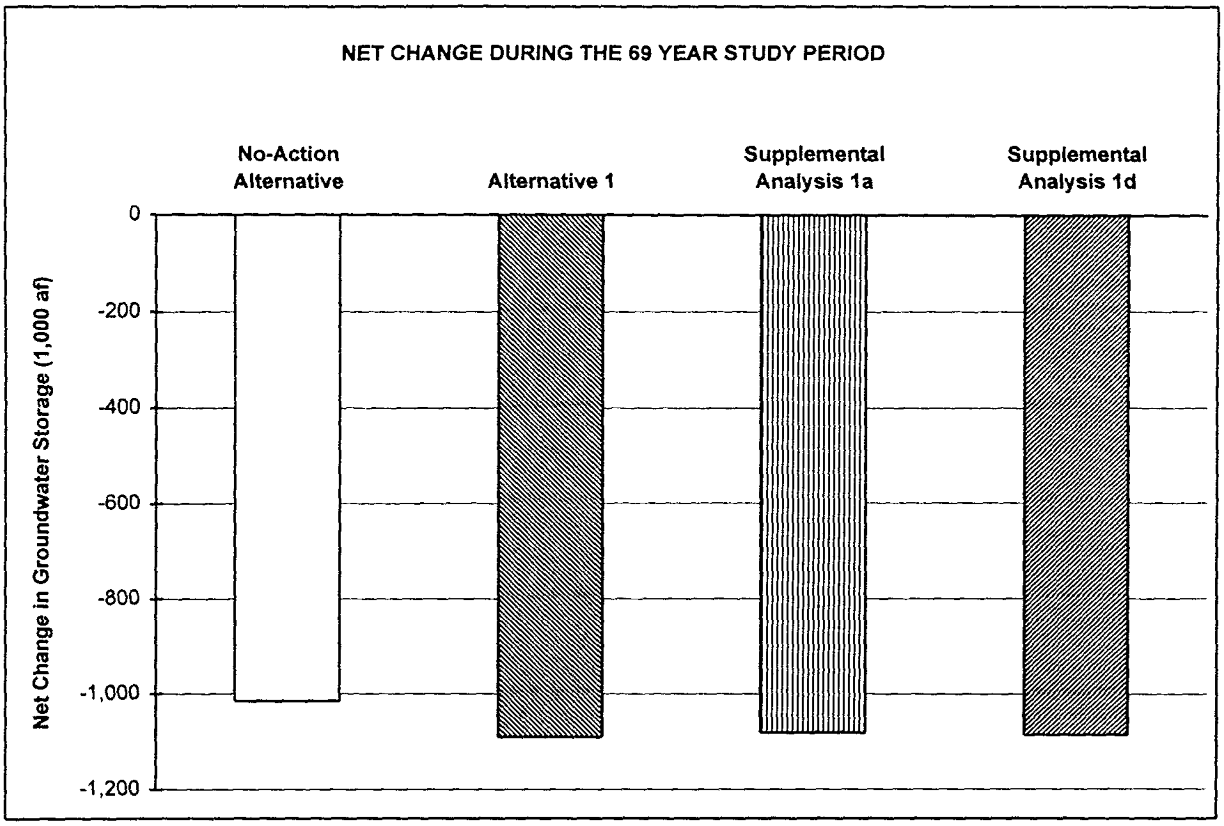

FIGURE B - 81
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 6

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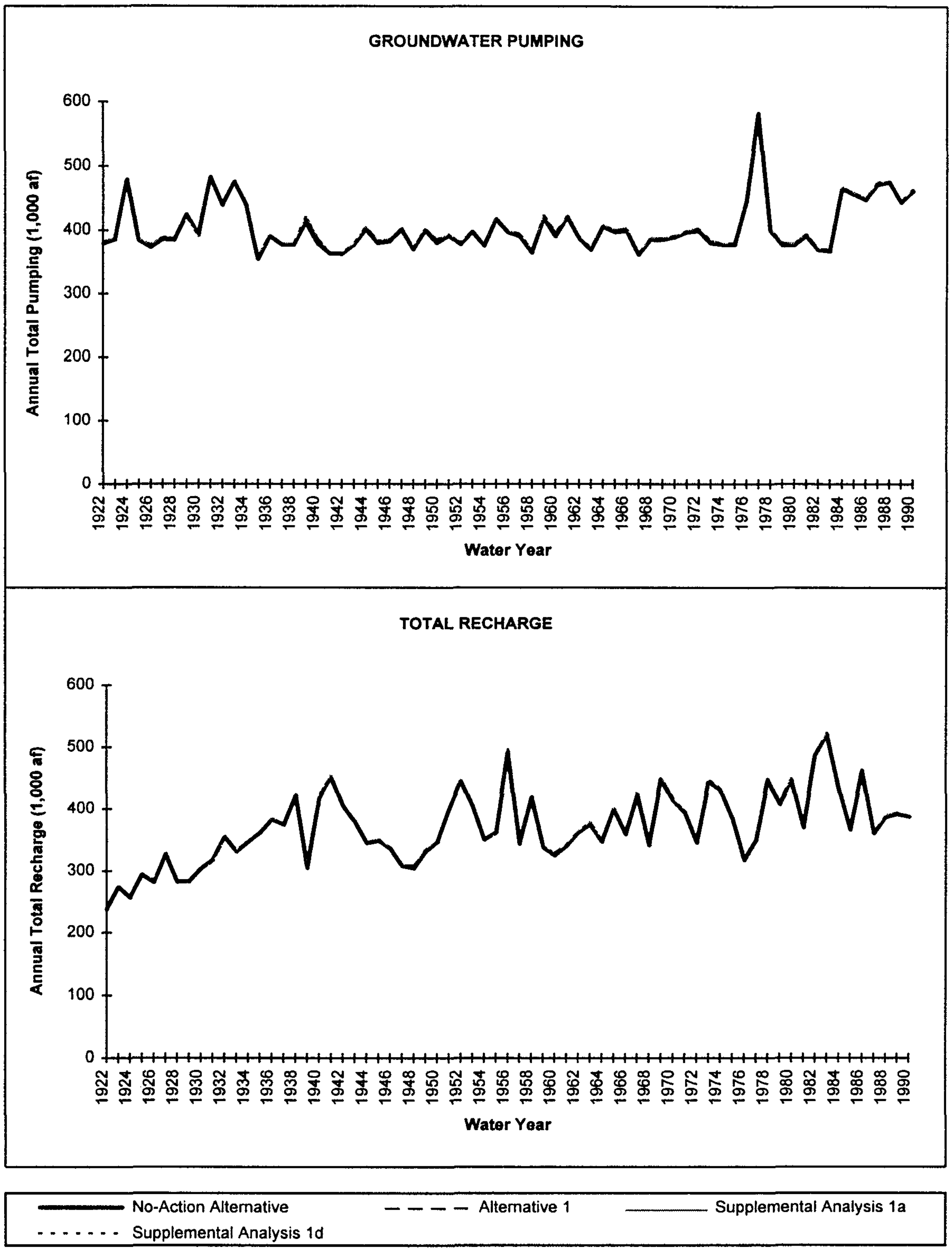

FIGURE B - 82
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 7

C—080657

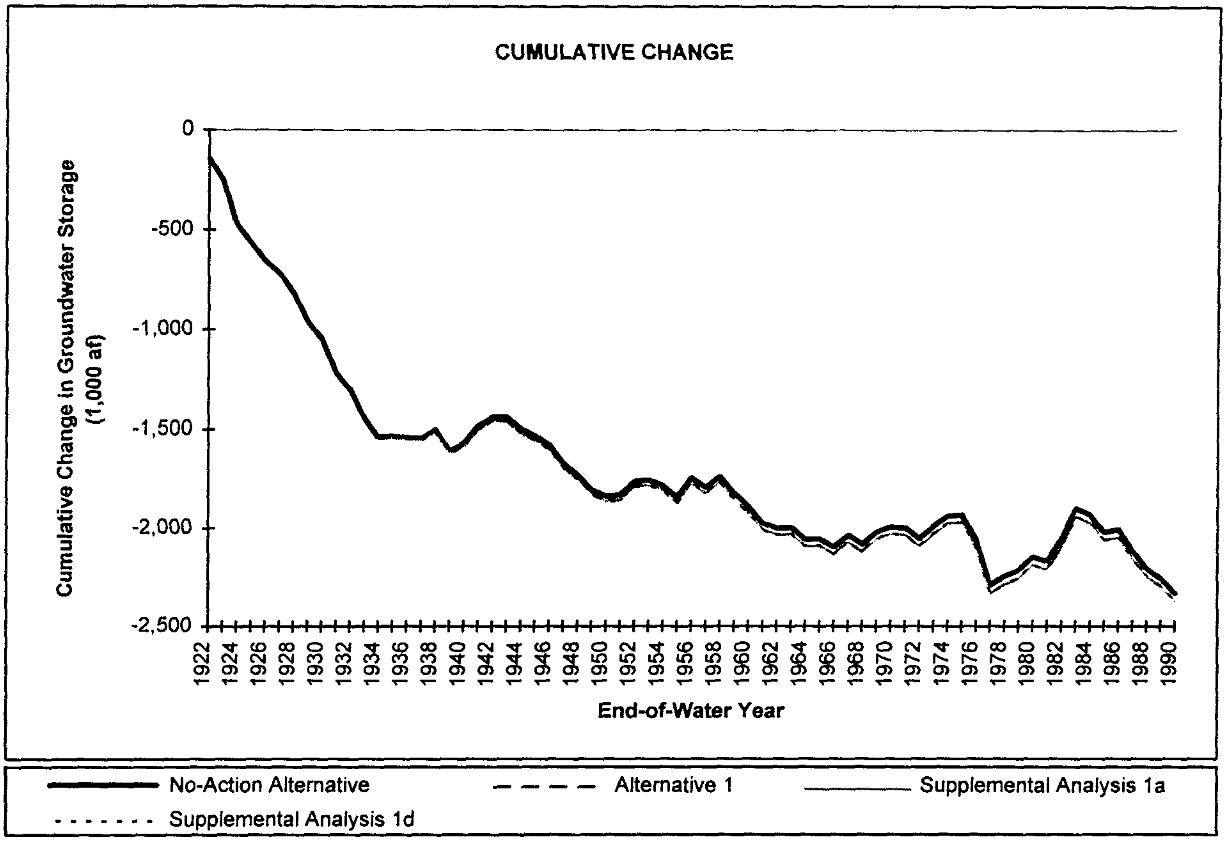

FIGURE B - 83
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 7

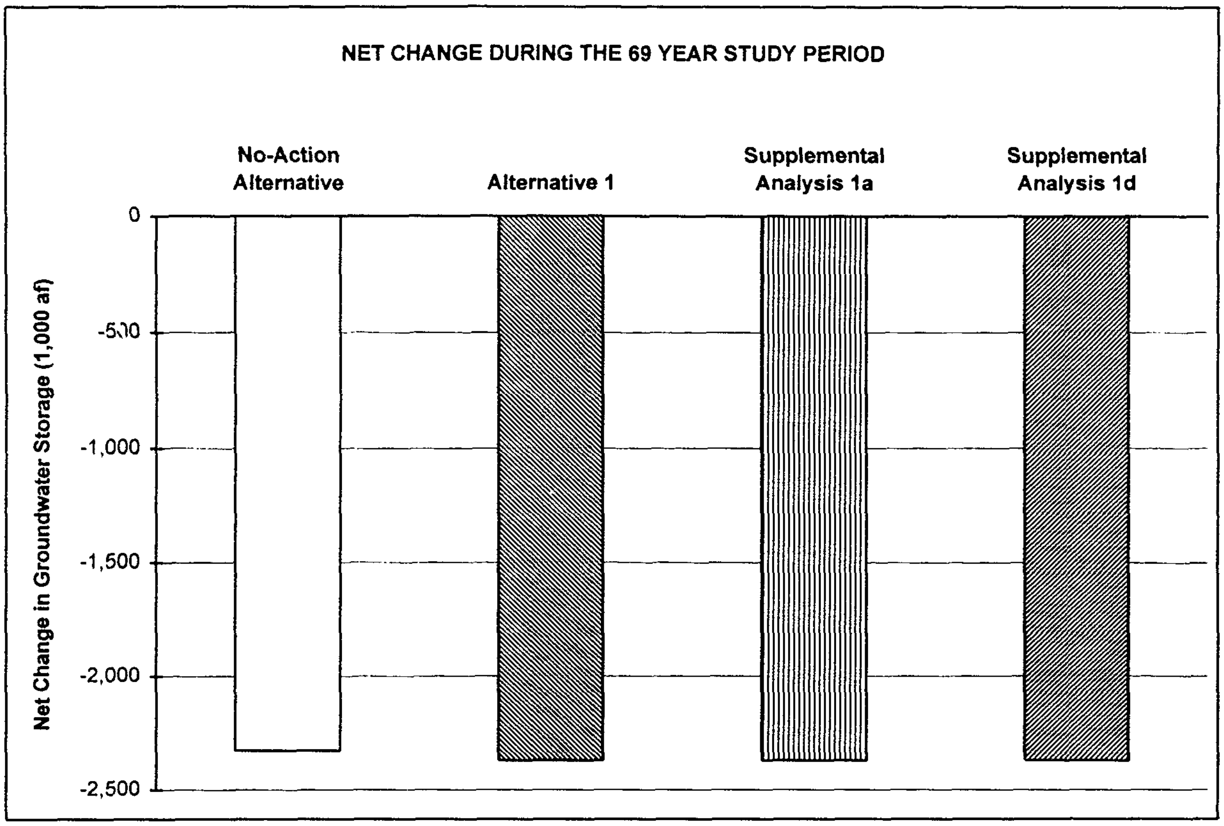

FIGURE B - 84
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 7

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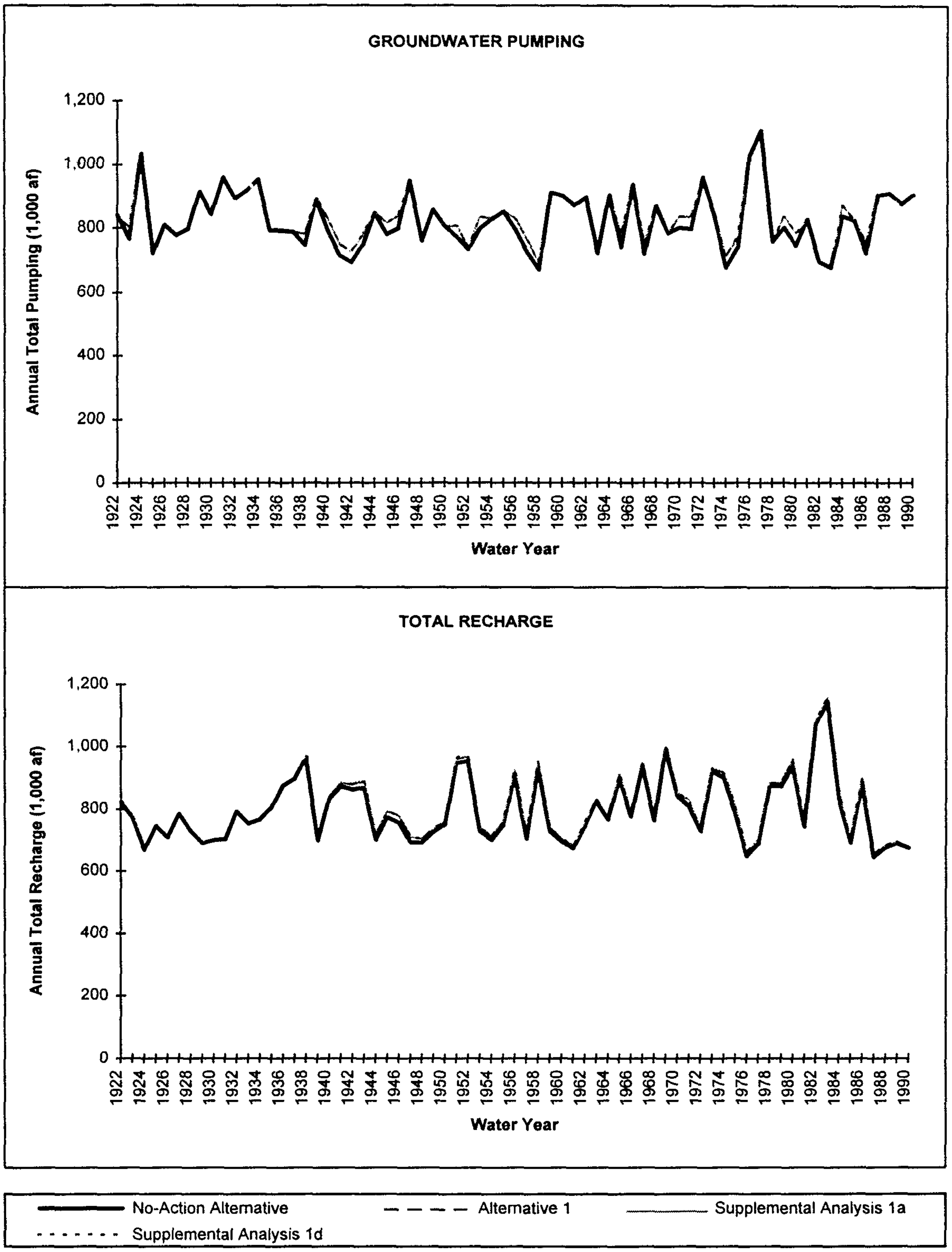

FIGURE B - 85
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 8

C—080661

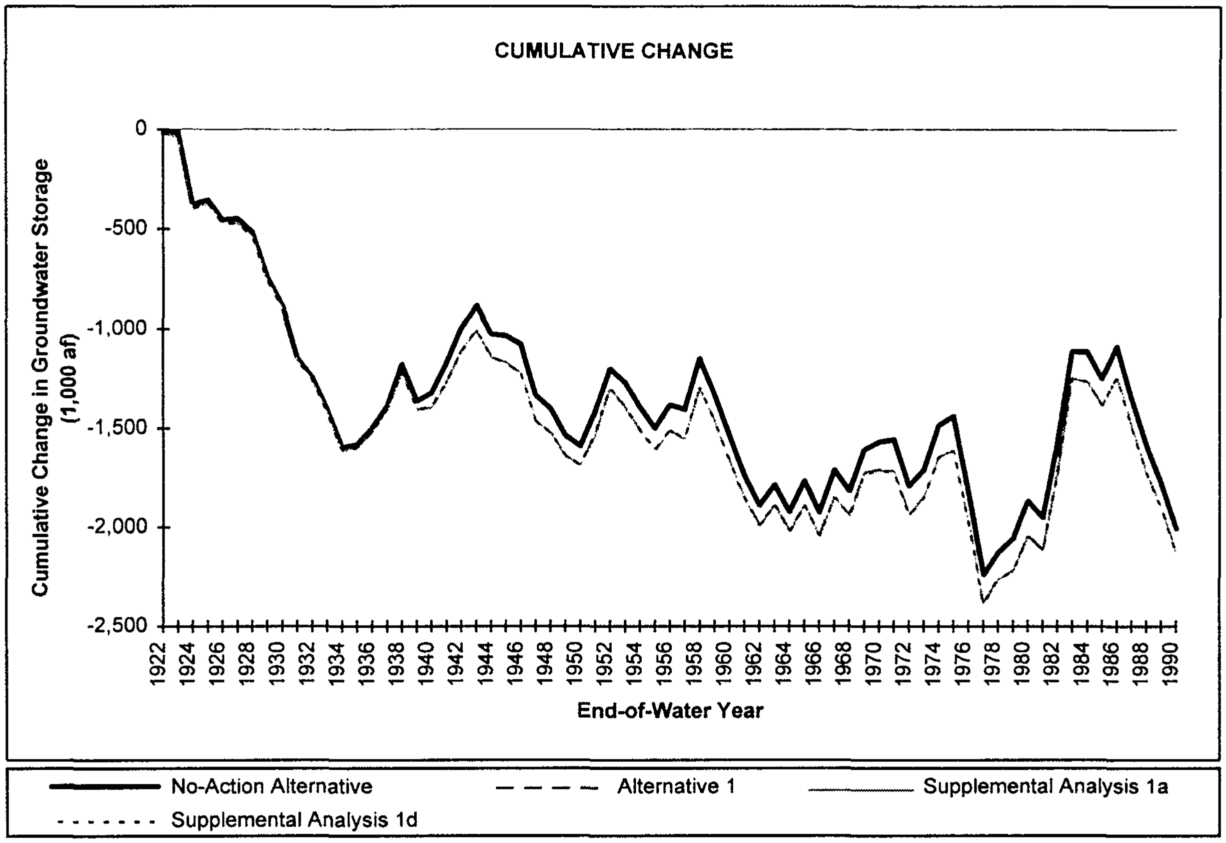

FIGURE B - 86
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 8

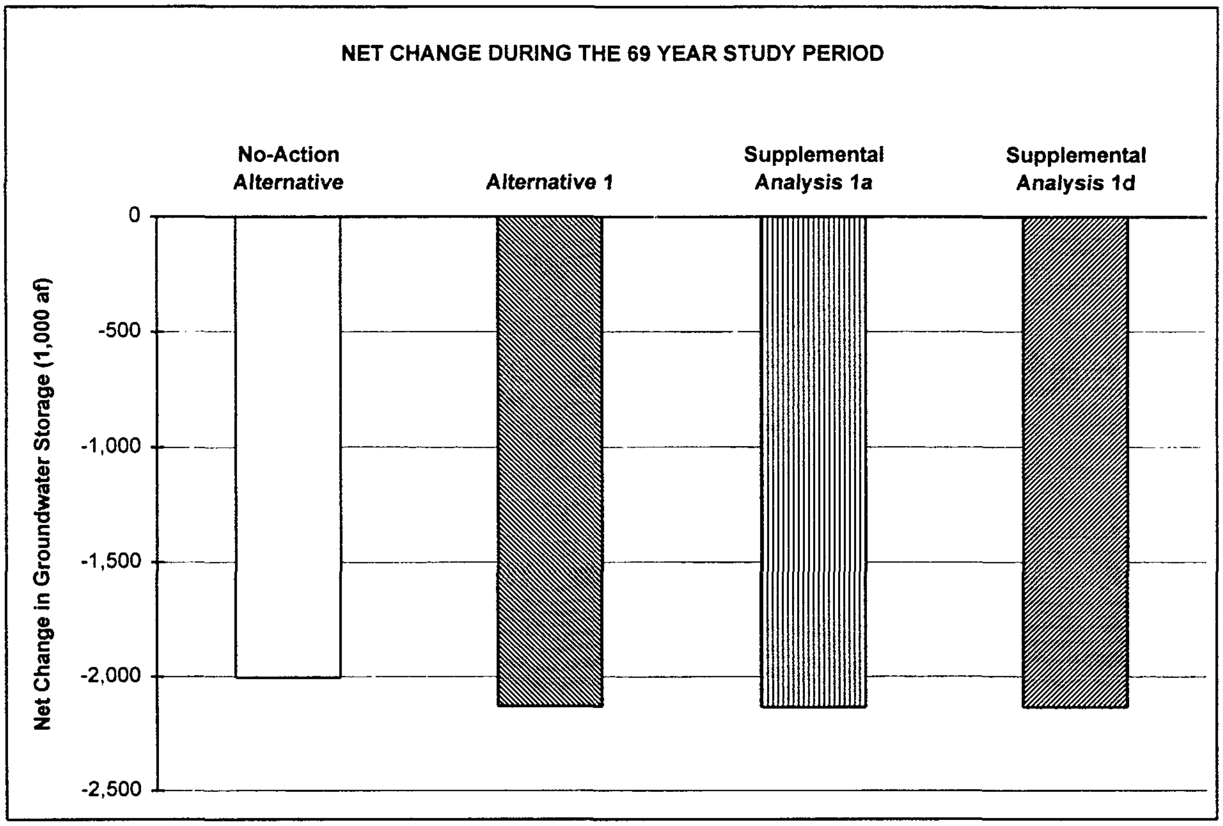

FIGURE B - 87
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 8

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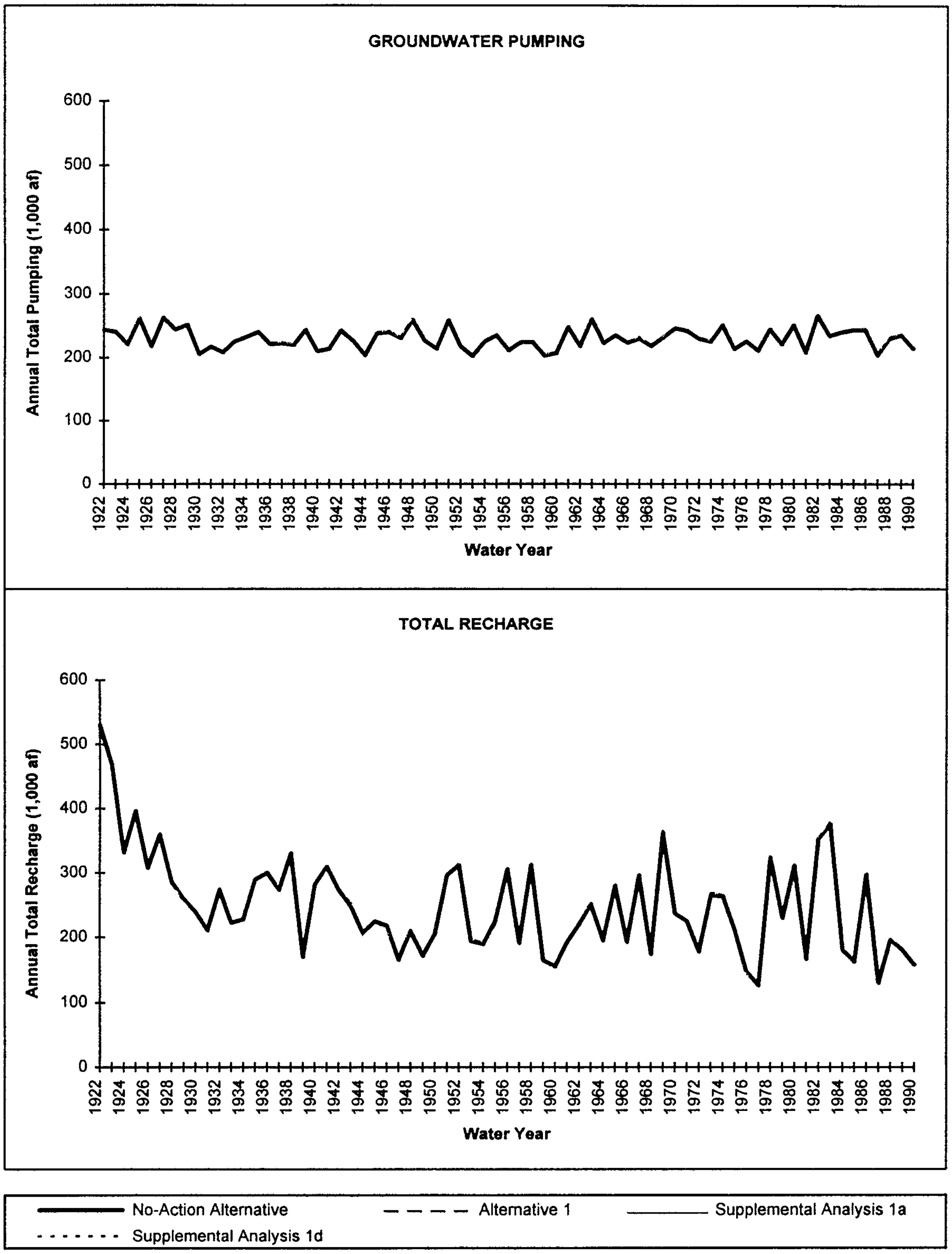

FIGURE B - 88
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 9

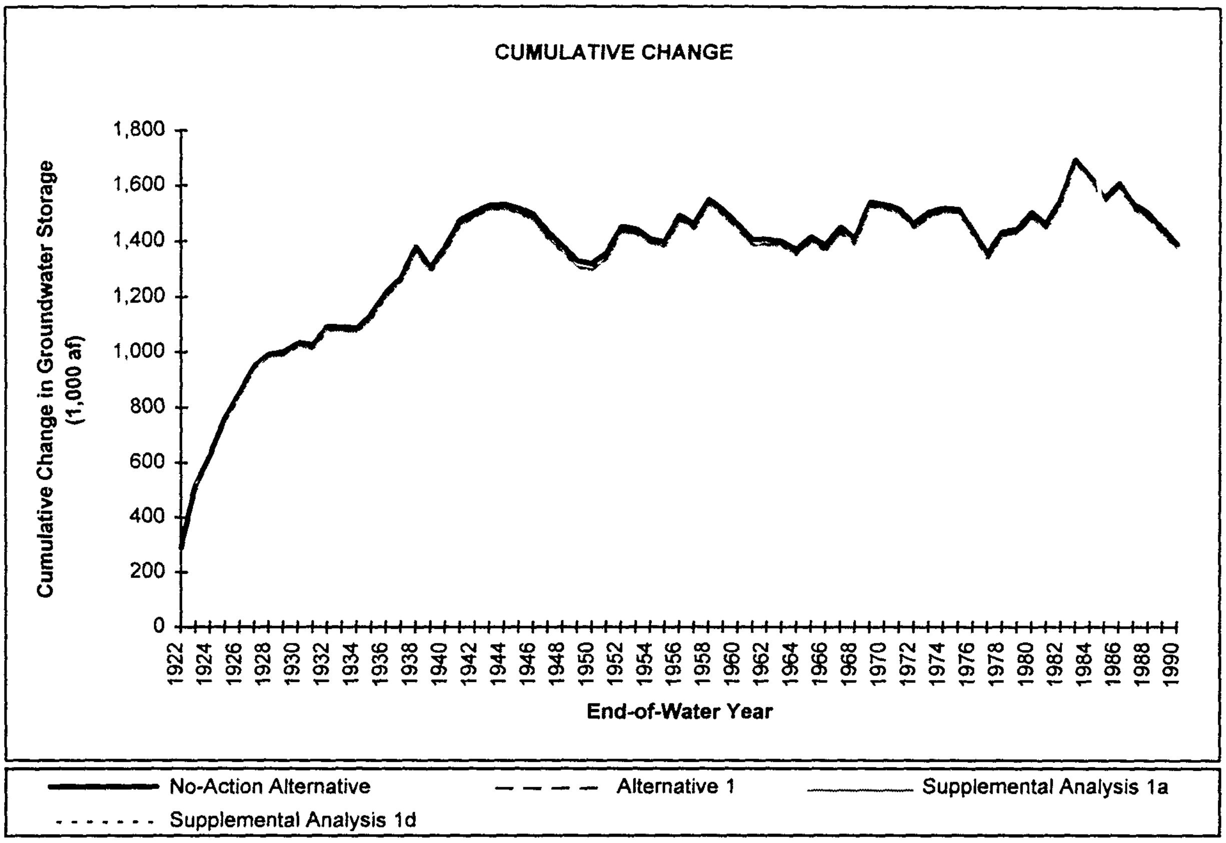

FIGURE B - 89
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 9

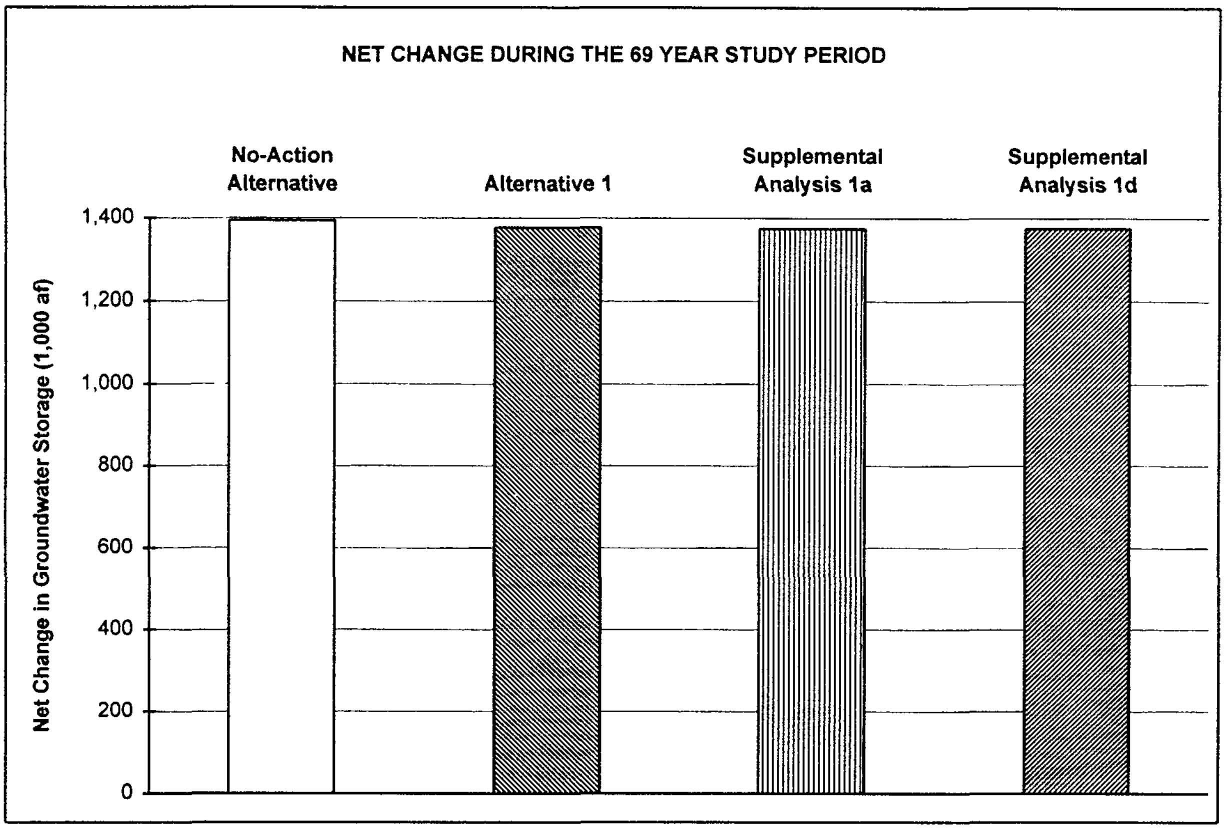

FIGURE B - 90
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 9

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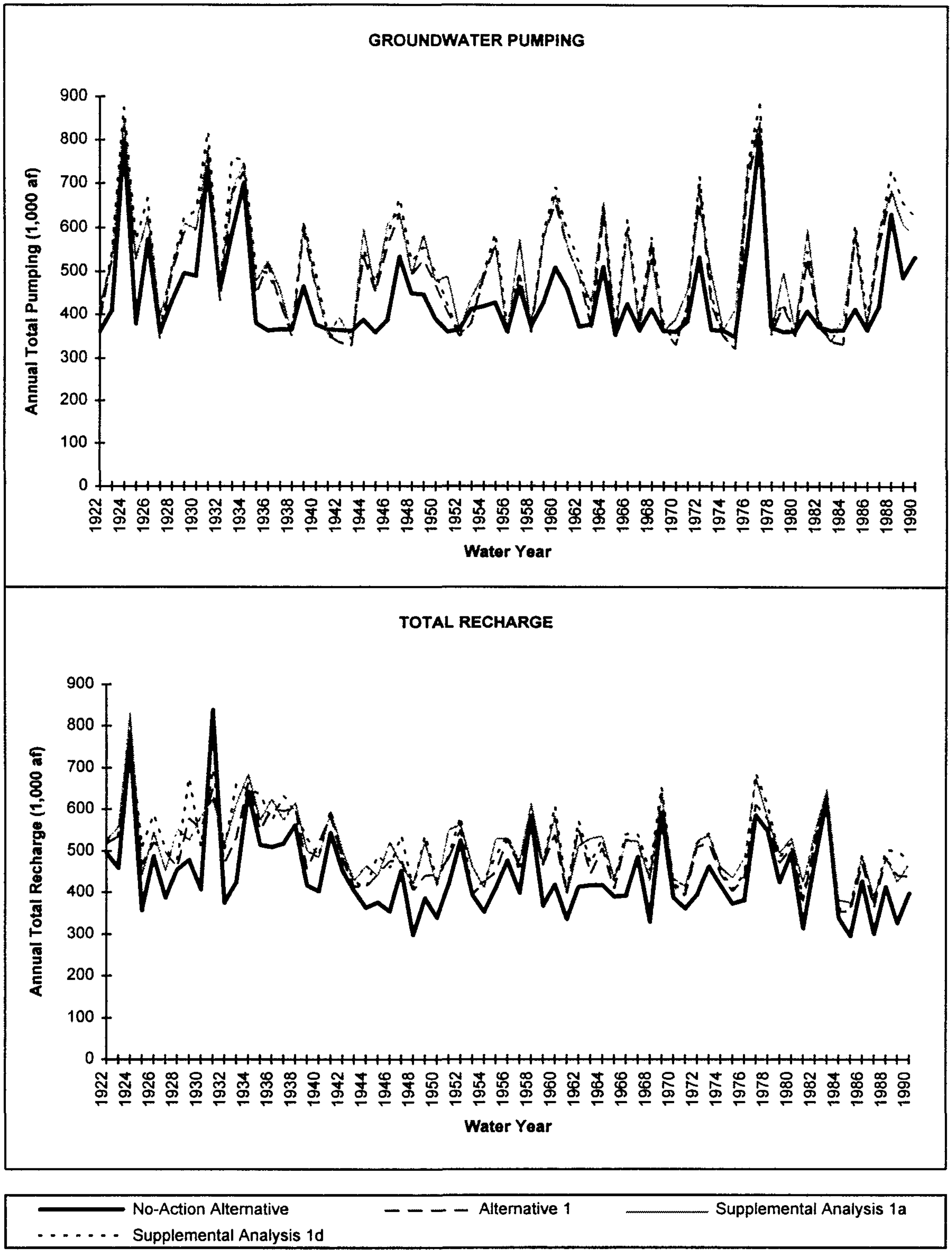

FIGURE B - 91
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 10

C —0 8 0 6 6 9

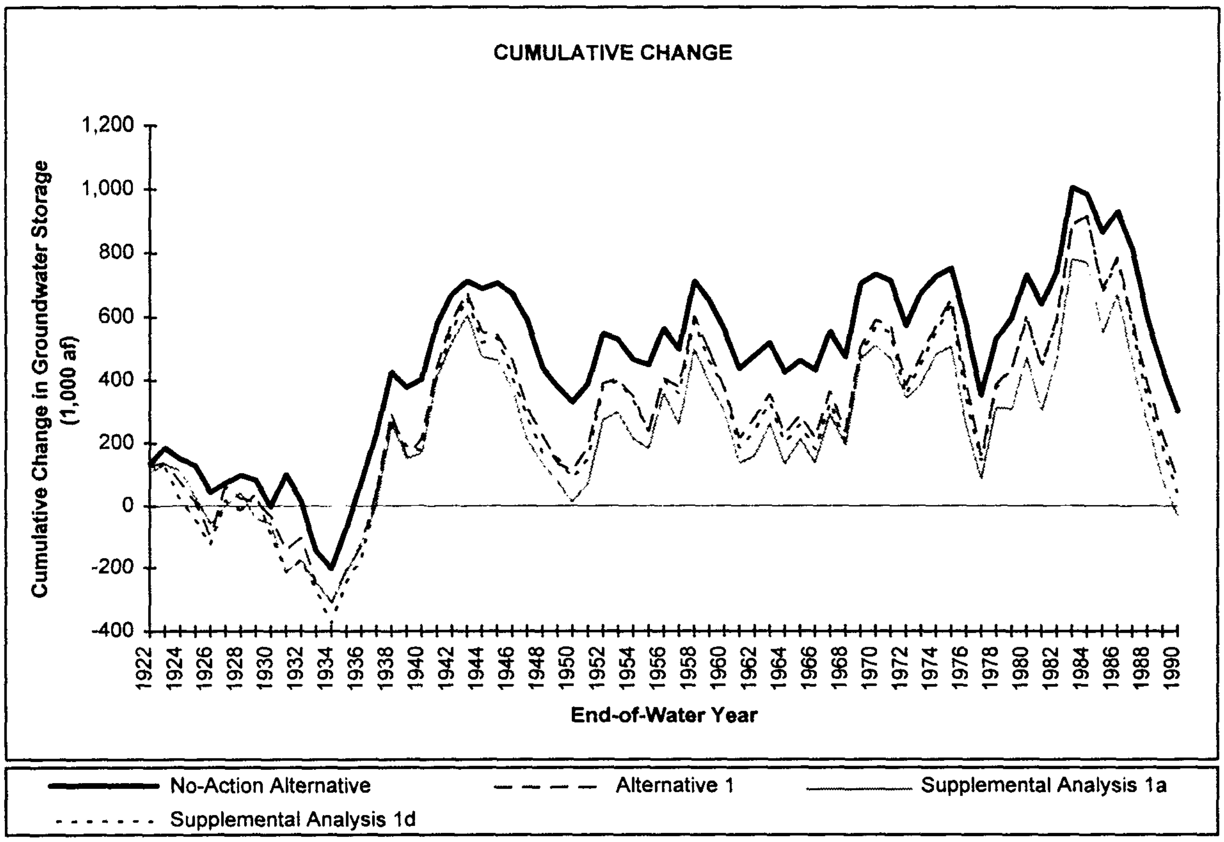

FIGURE B - 92
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 10

C —0 8 0 6 7 0

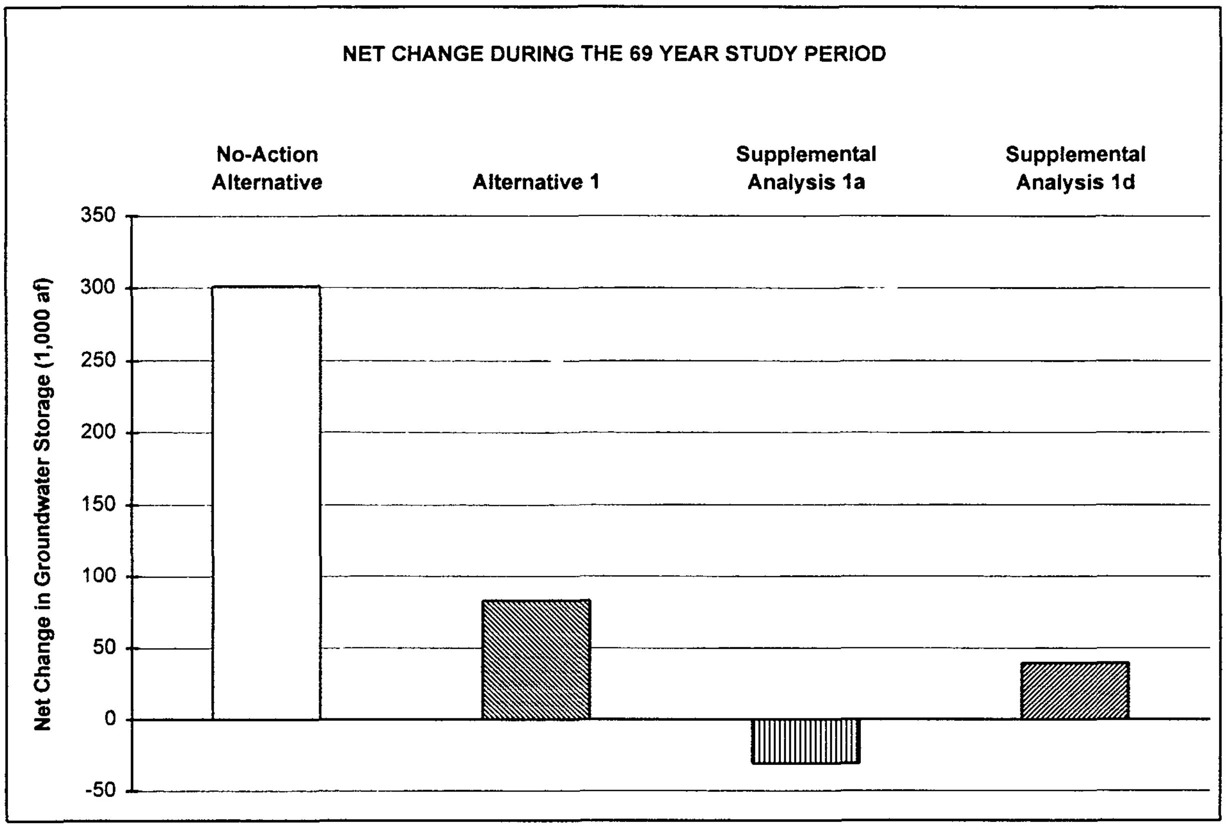

FIGURE B - 93
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 10

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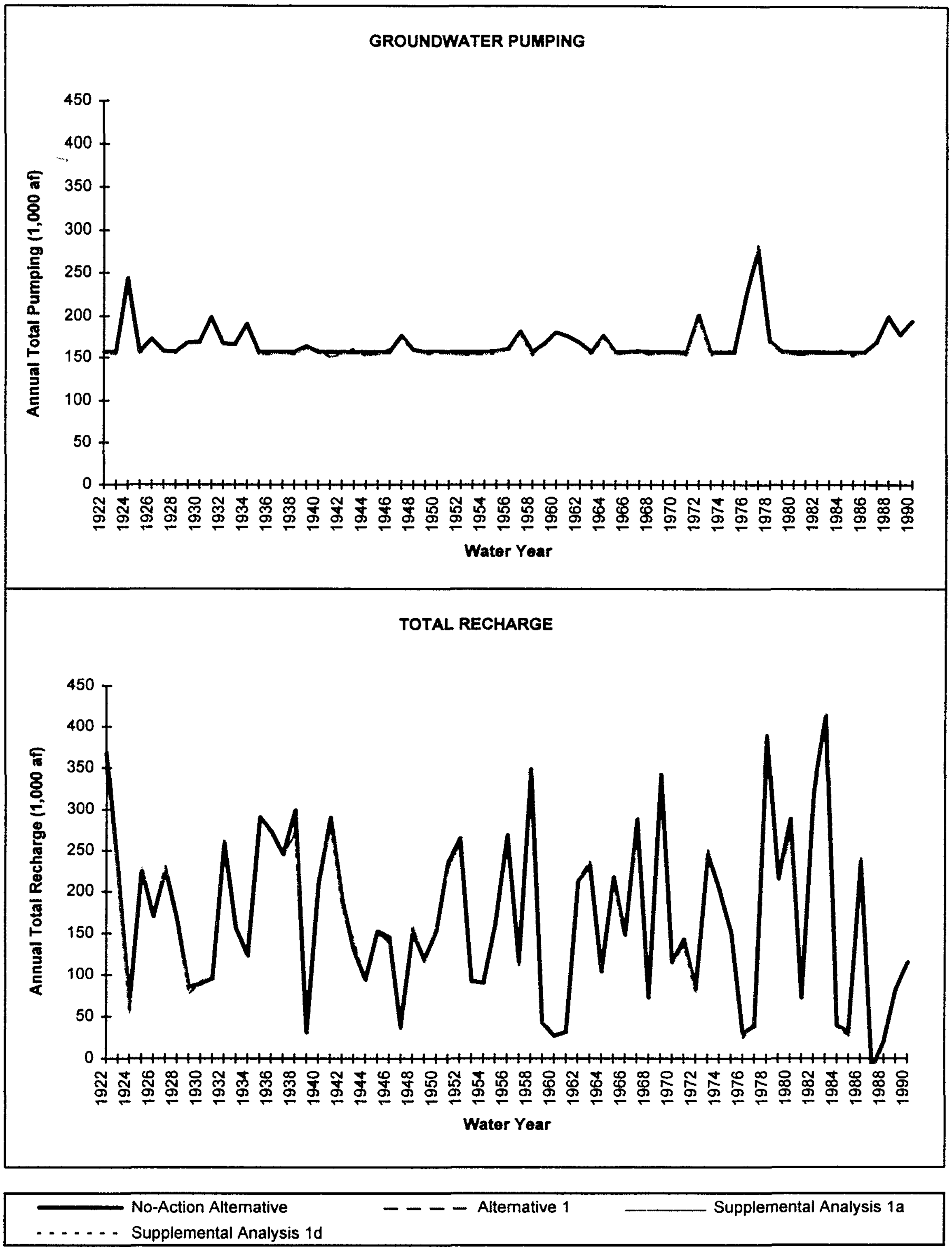

FIGURE B - 94
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 11

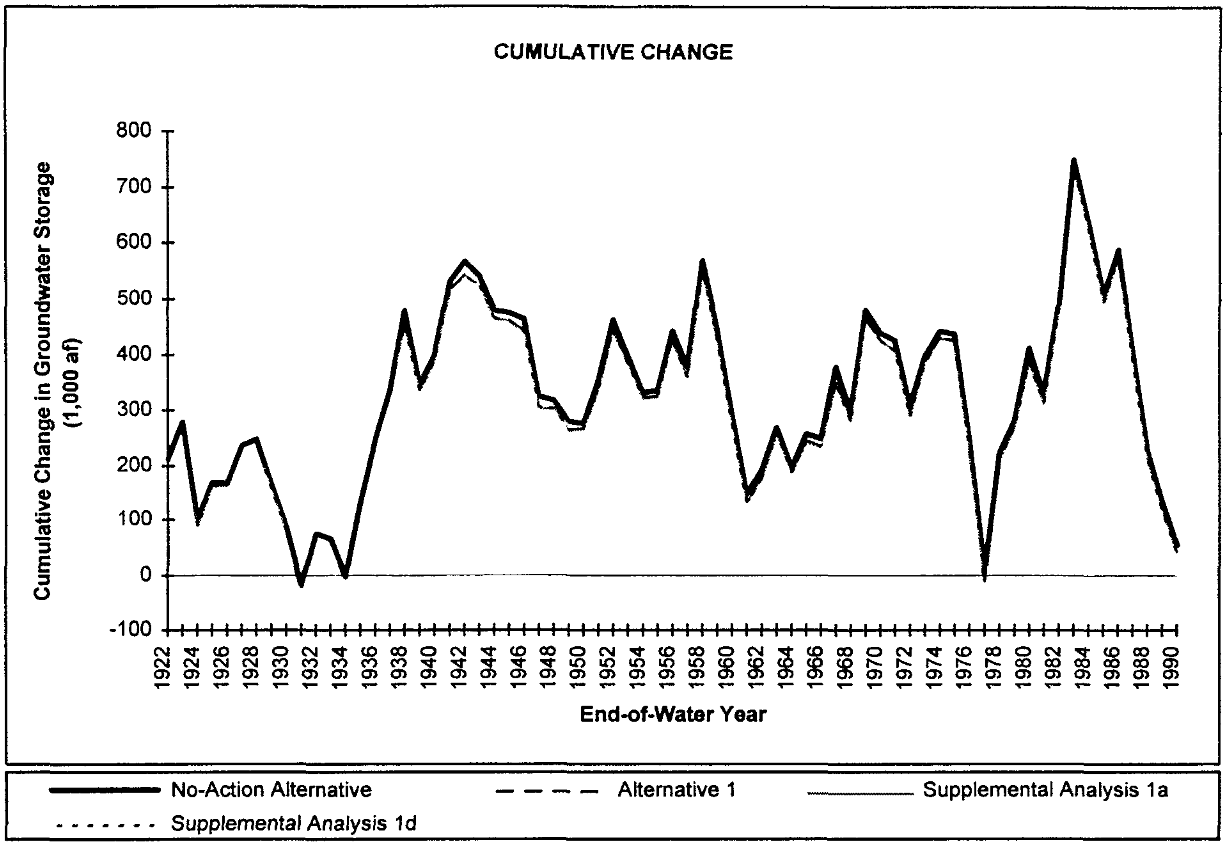

FIGURE B - 95
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 11

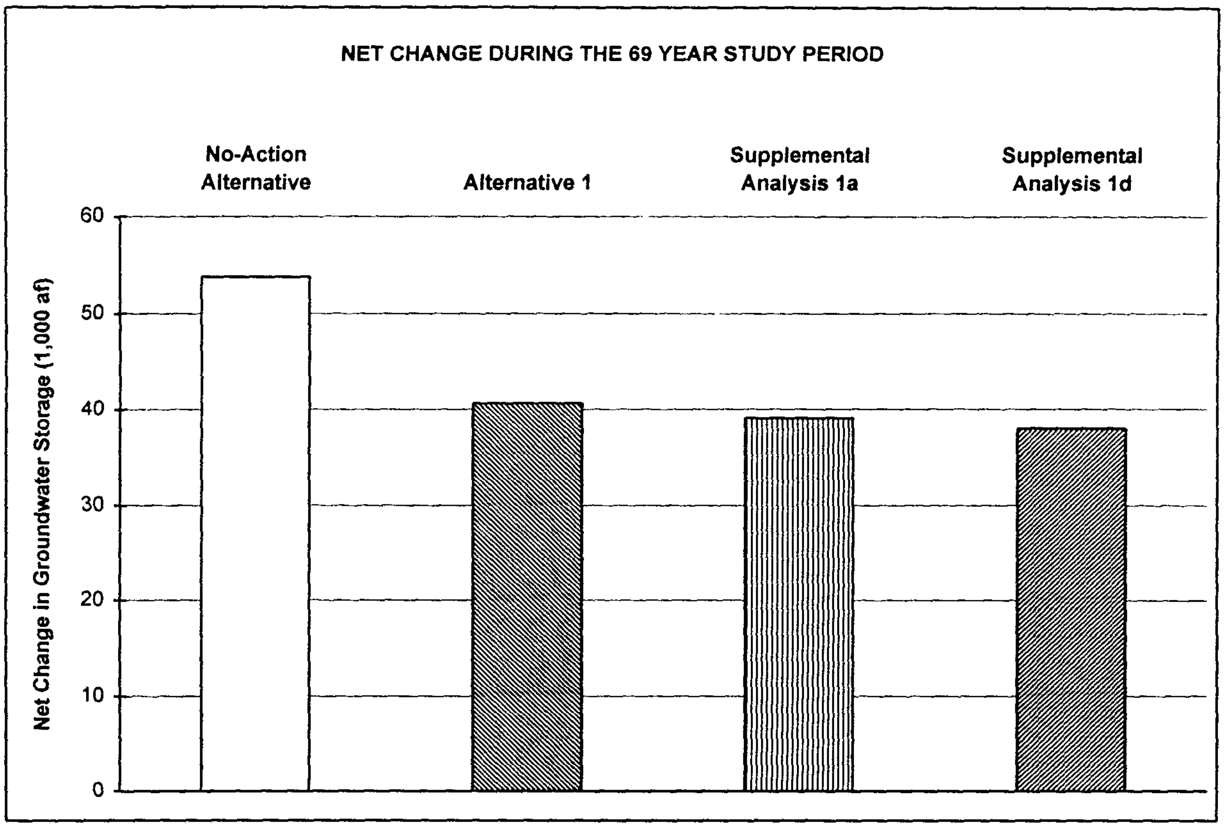

FIGURE B - 96
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 11

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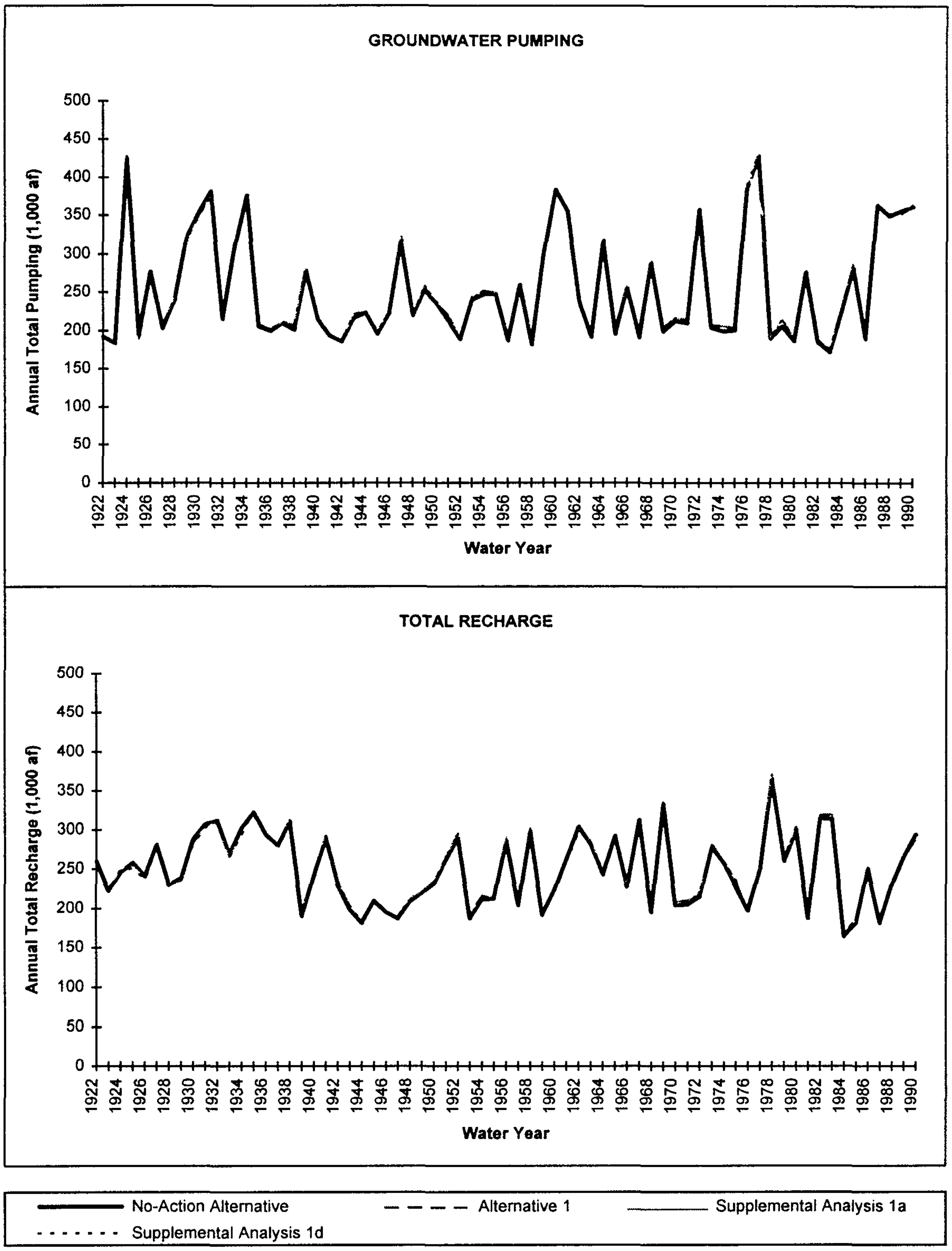

FIGURE B - 97
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 12

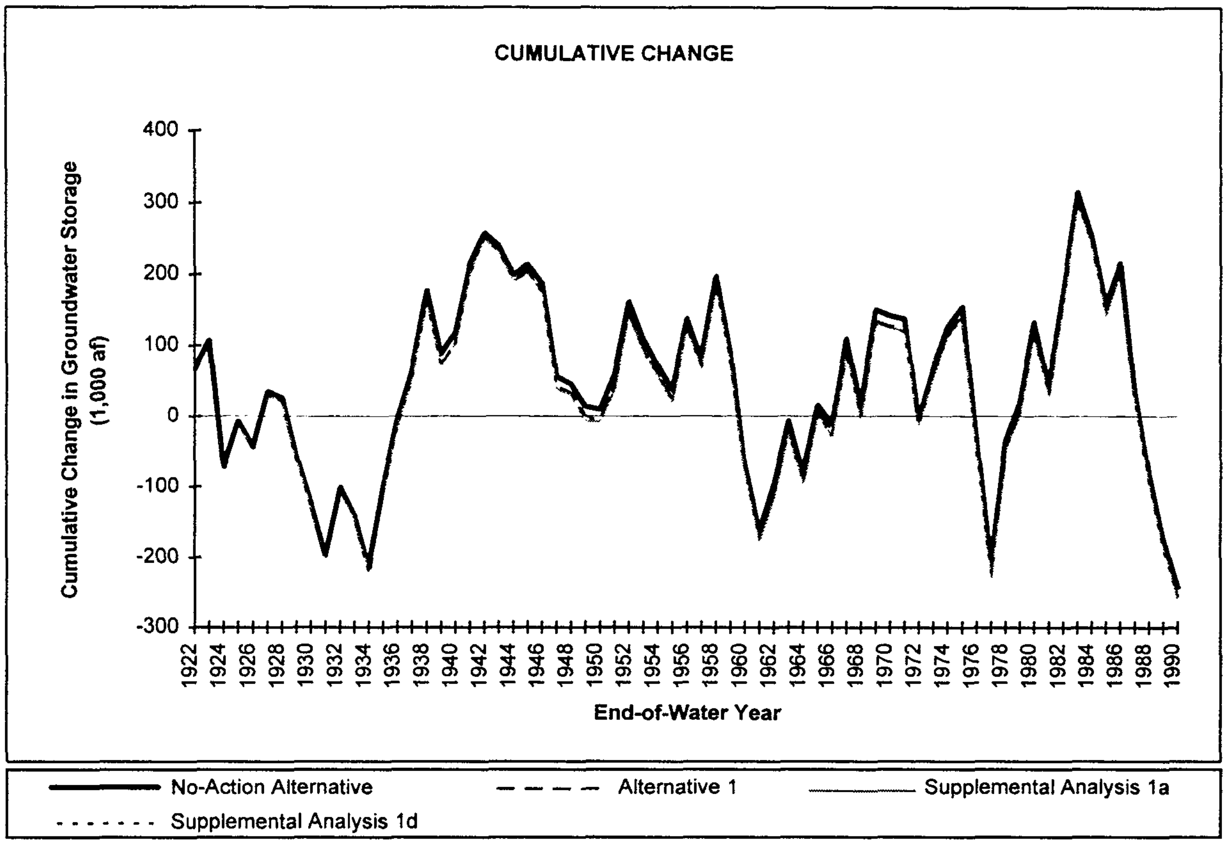

FIGURE B - 98
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 12

C—080678

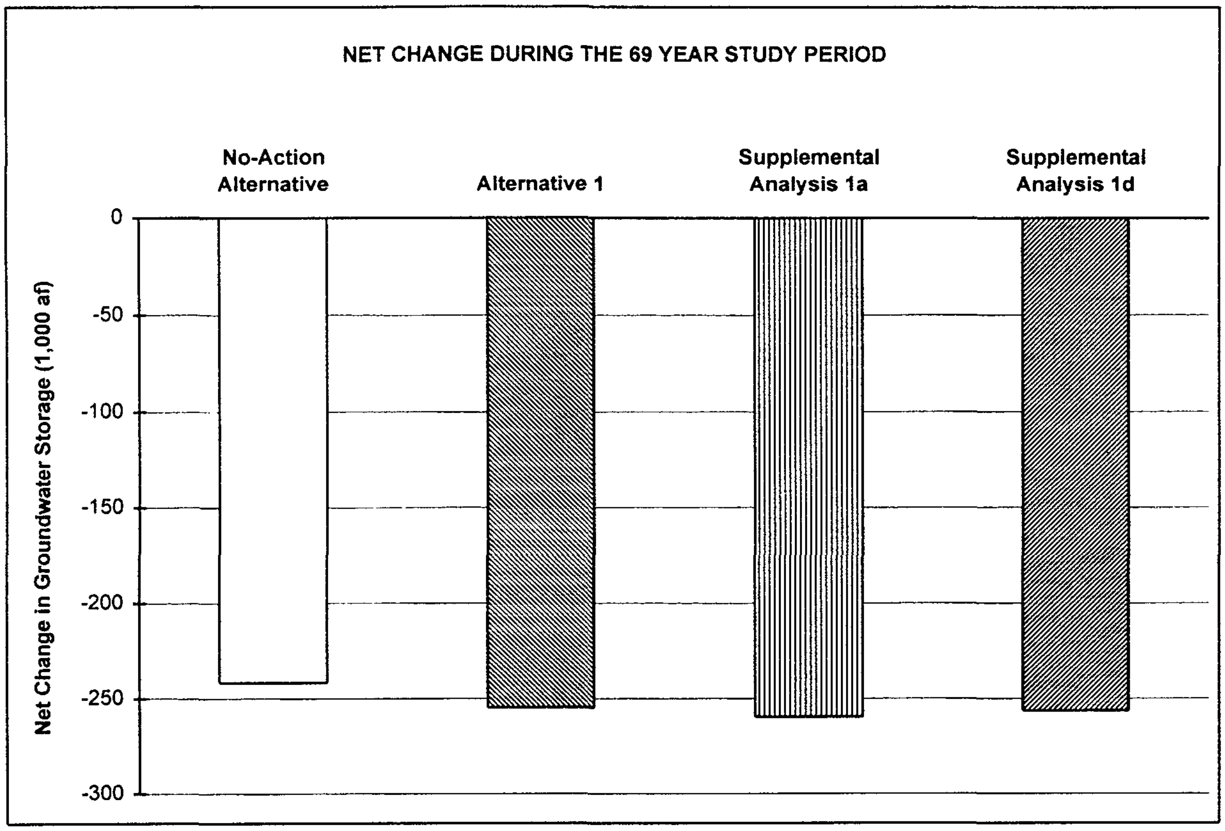

FIGURE B - 99
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 12

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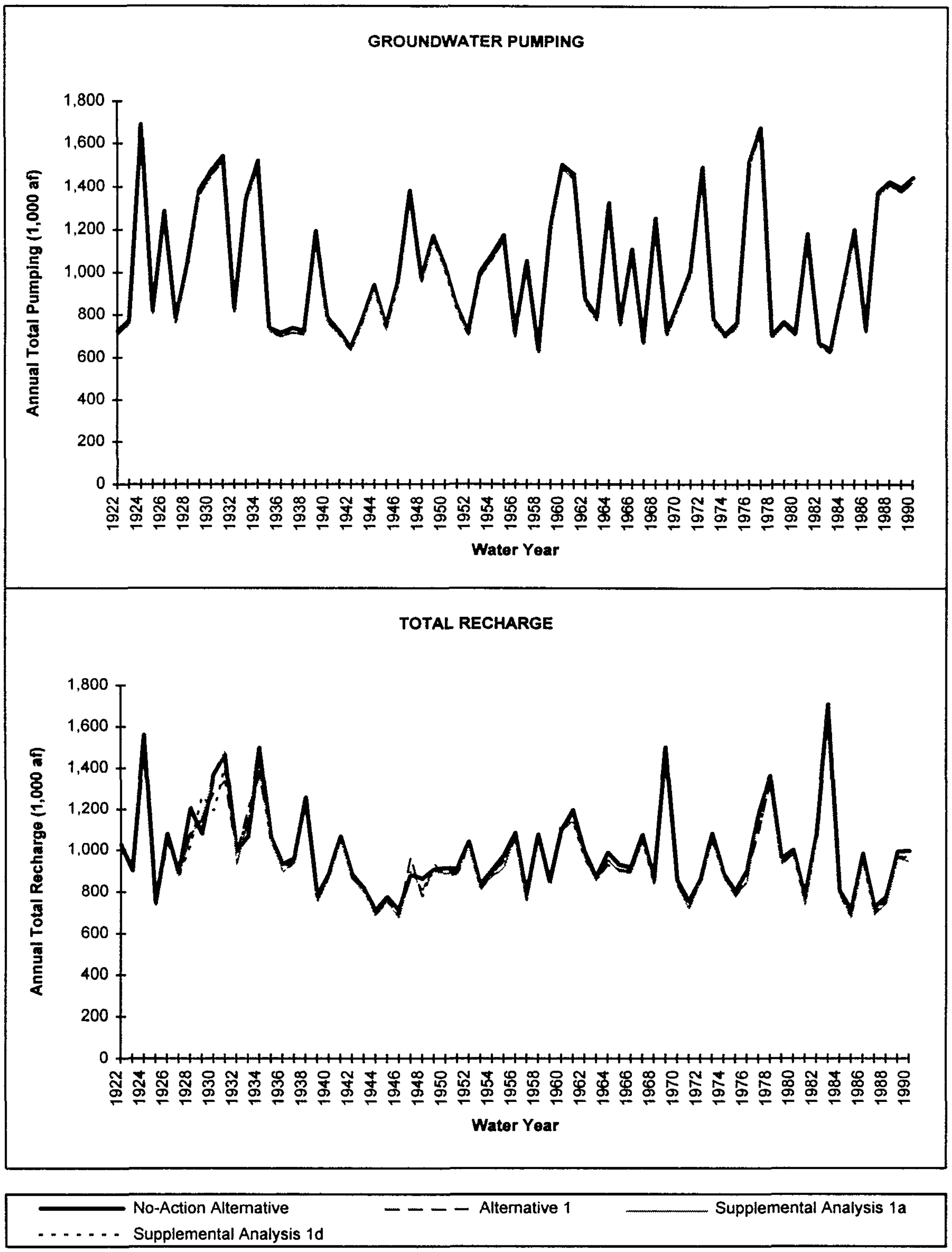

FIGURE B - 100
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 13

C—080681

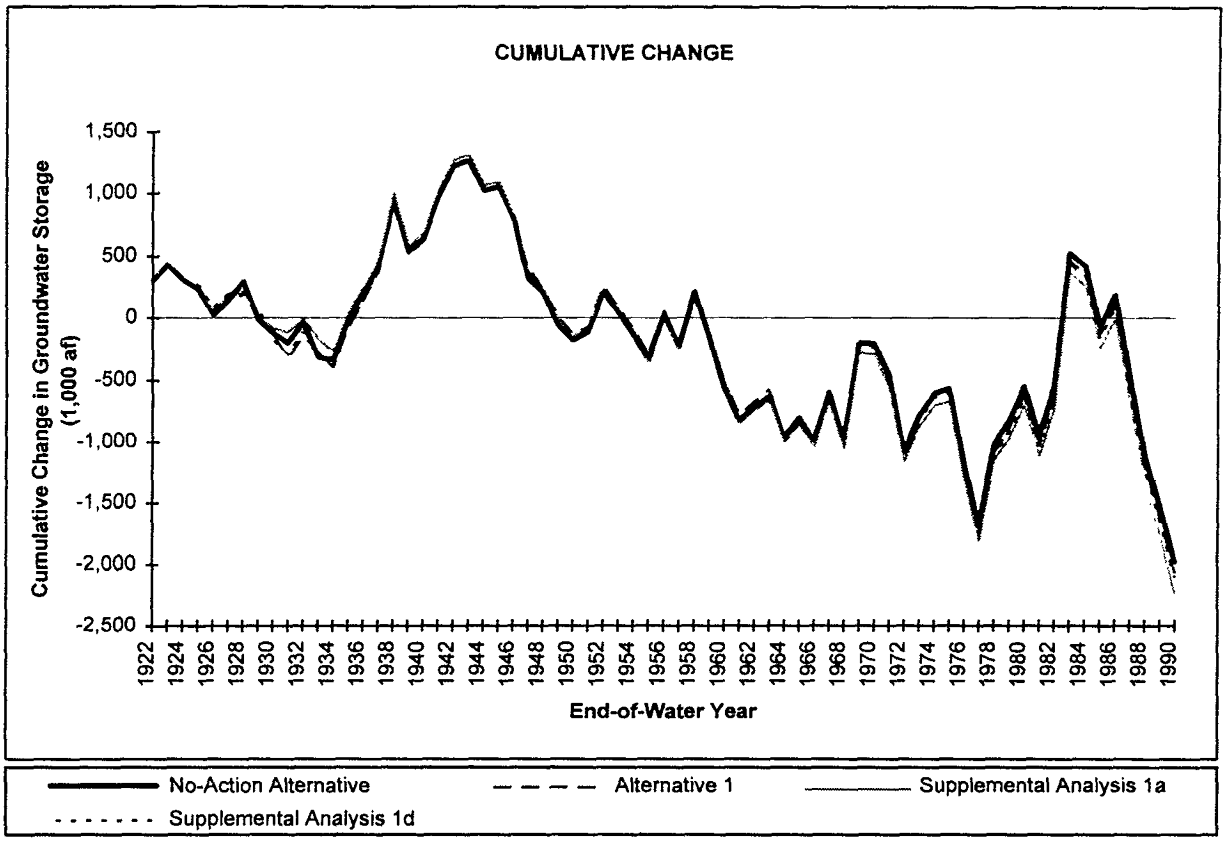

FIGURE B - 101
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 13

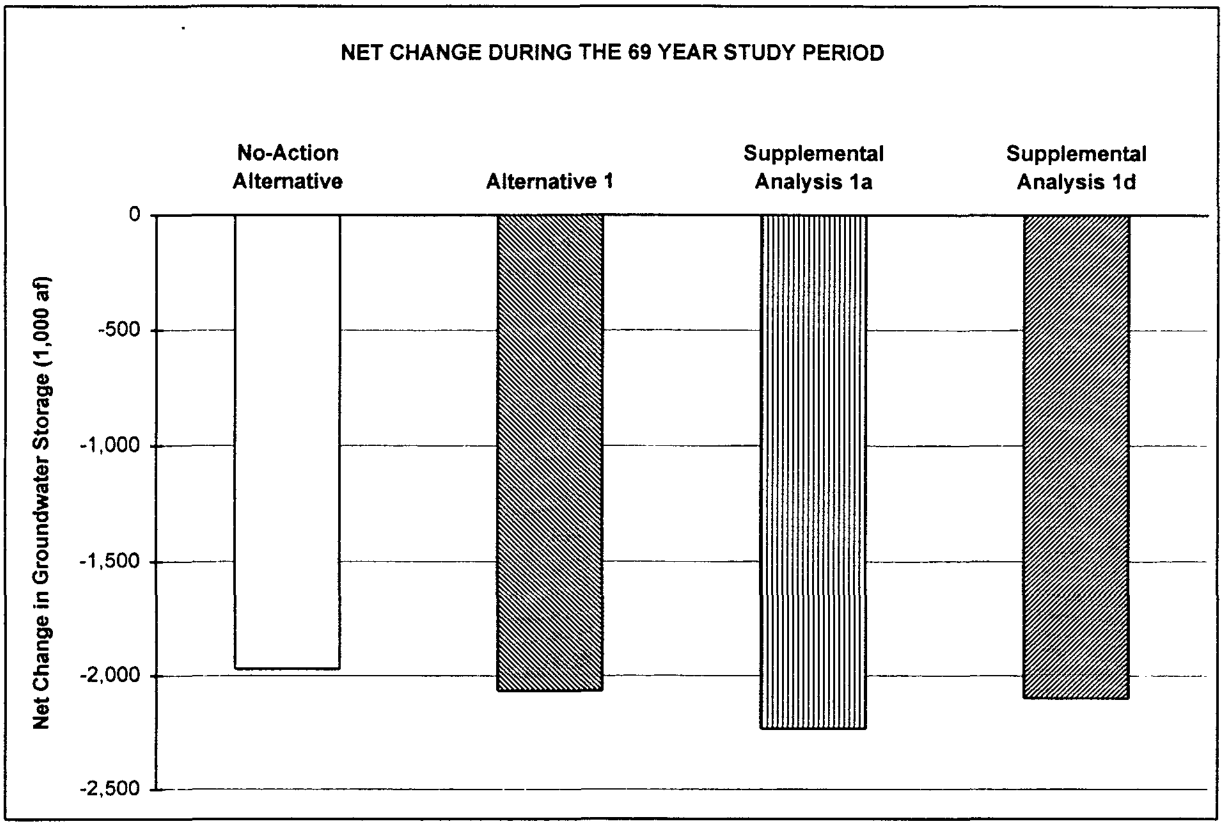

FIGURE B - 102
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 13

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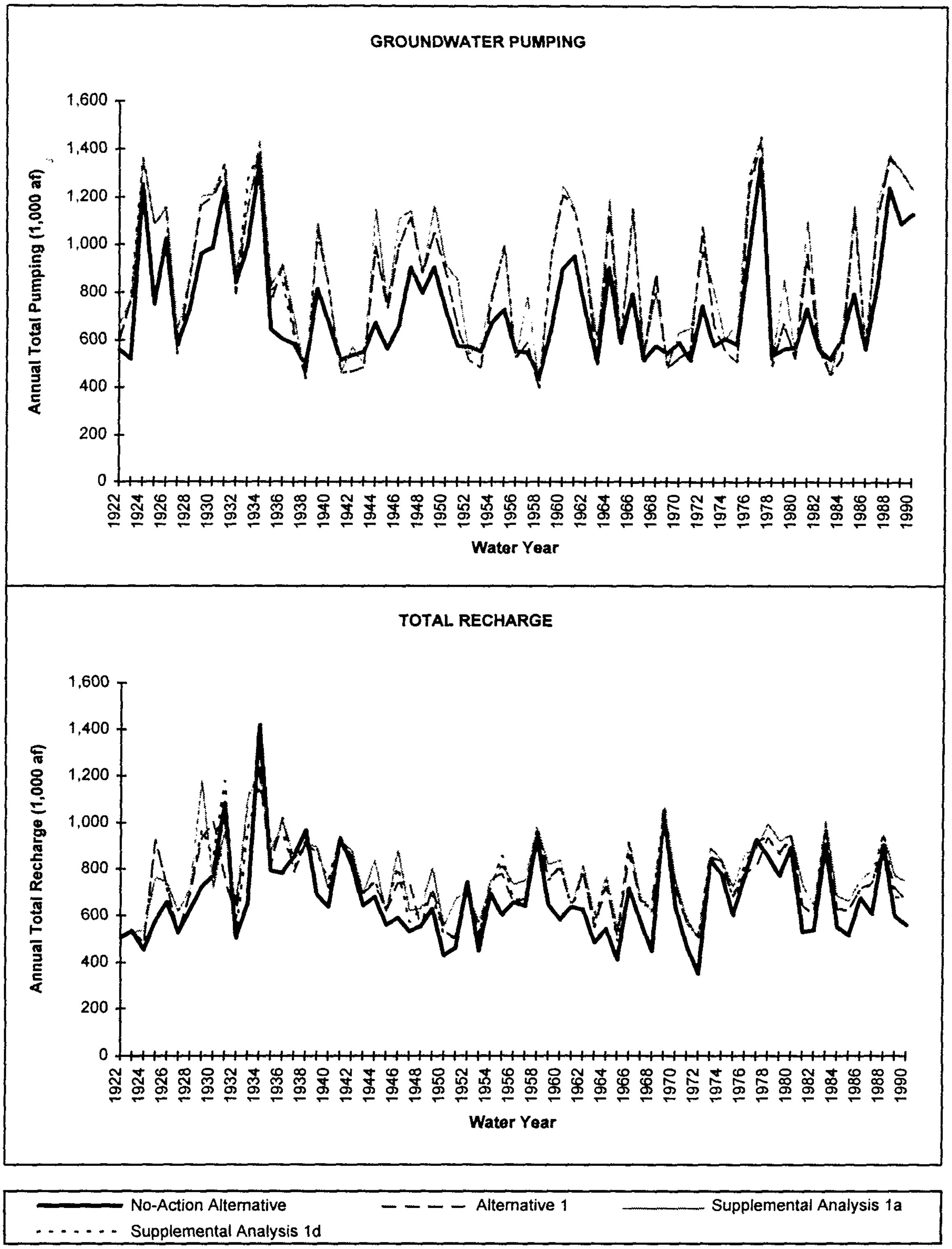

FIGURE B - 103
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 14

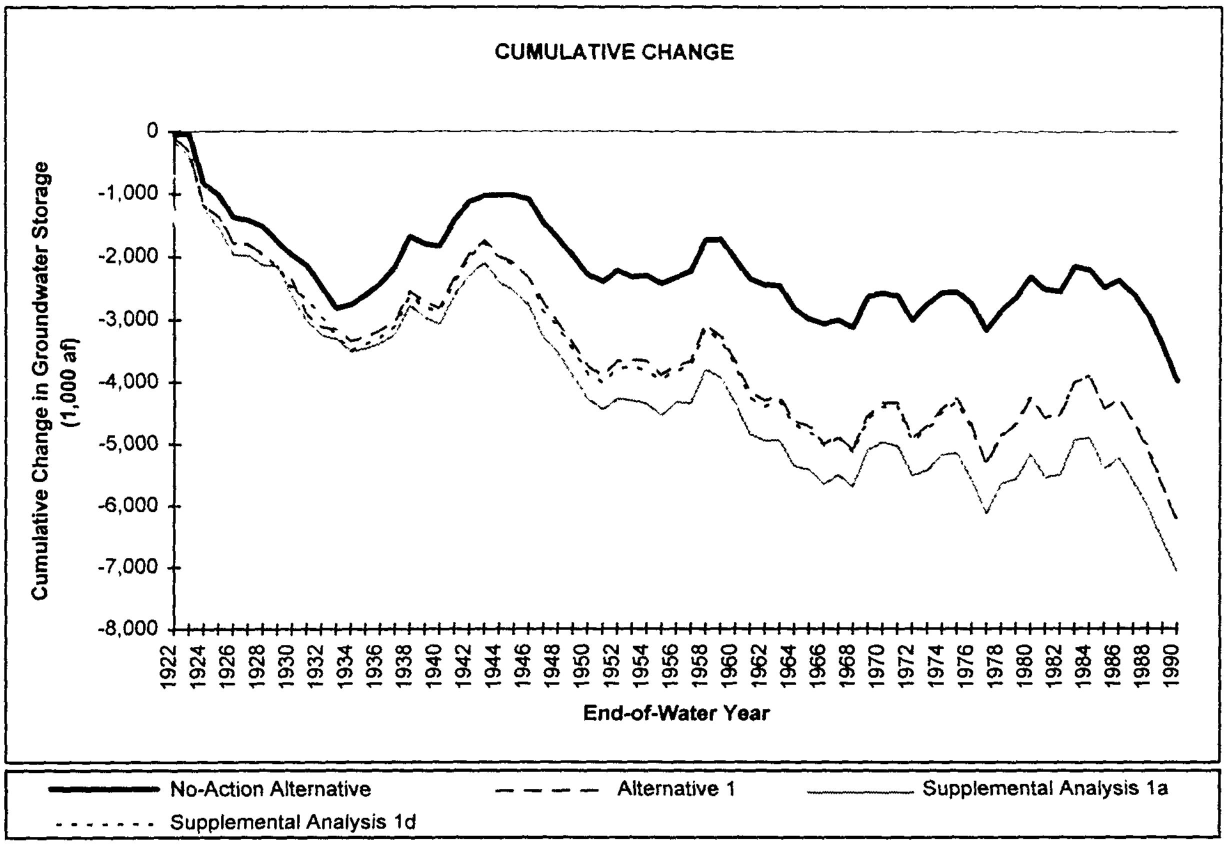

FIGURE B - 104
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 14

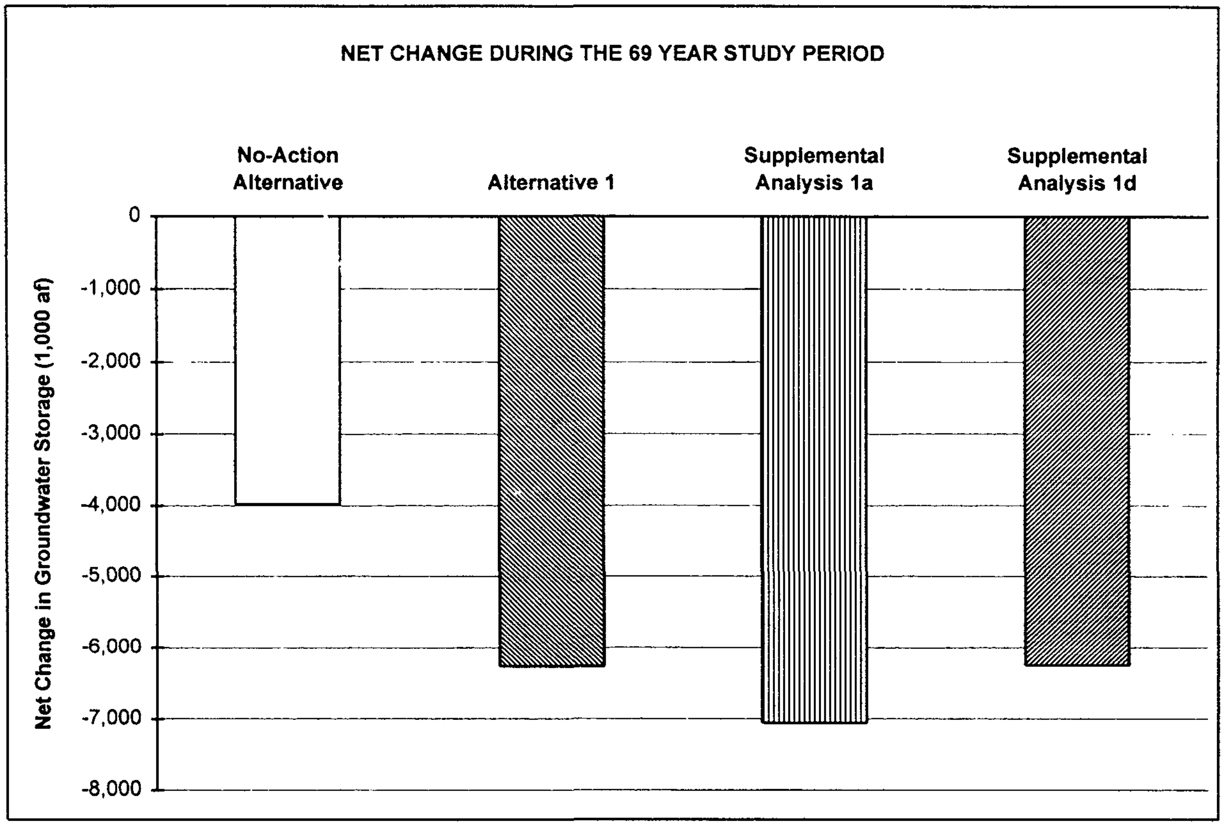

FIGURE B - 105
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 14

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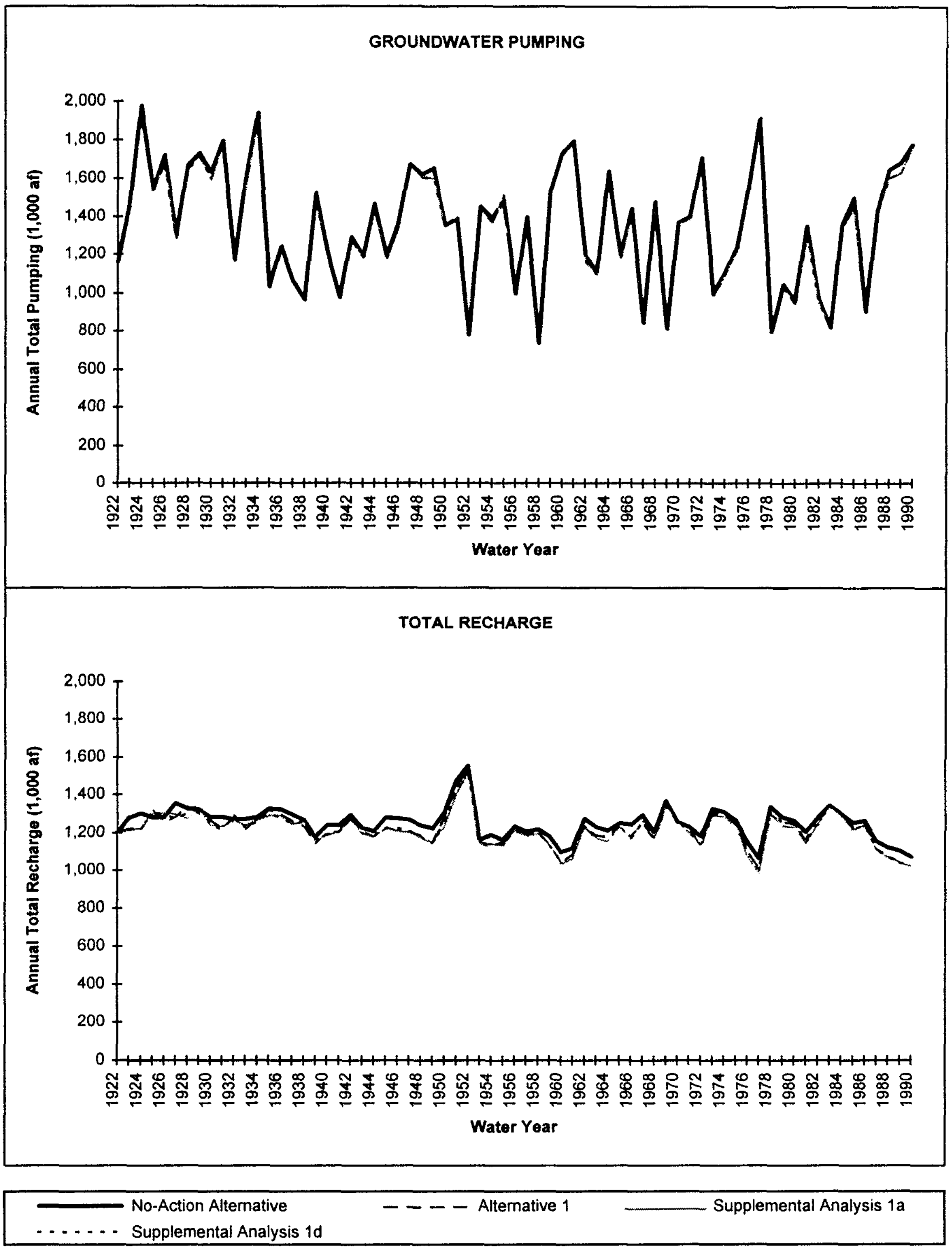

FIGURE B - 106
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 15

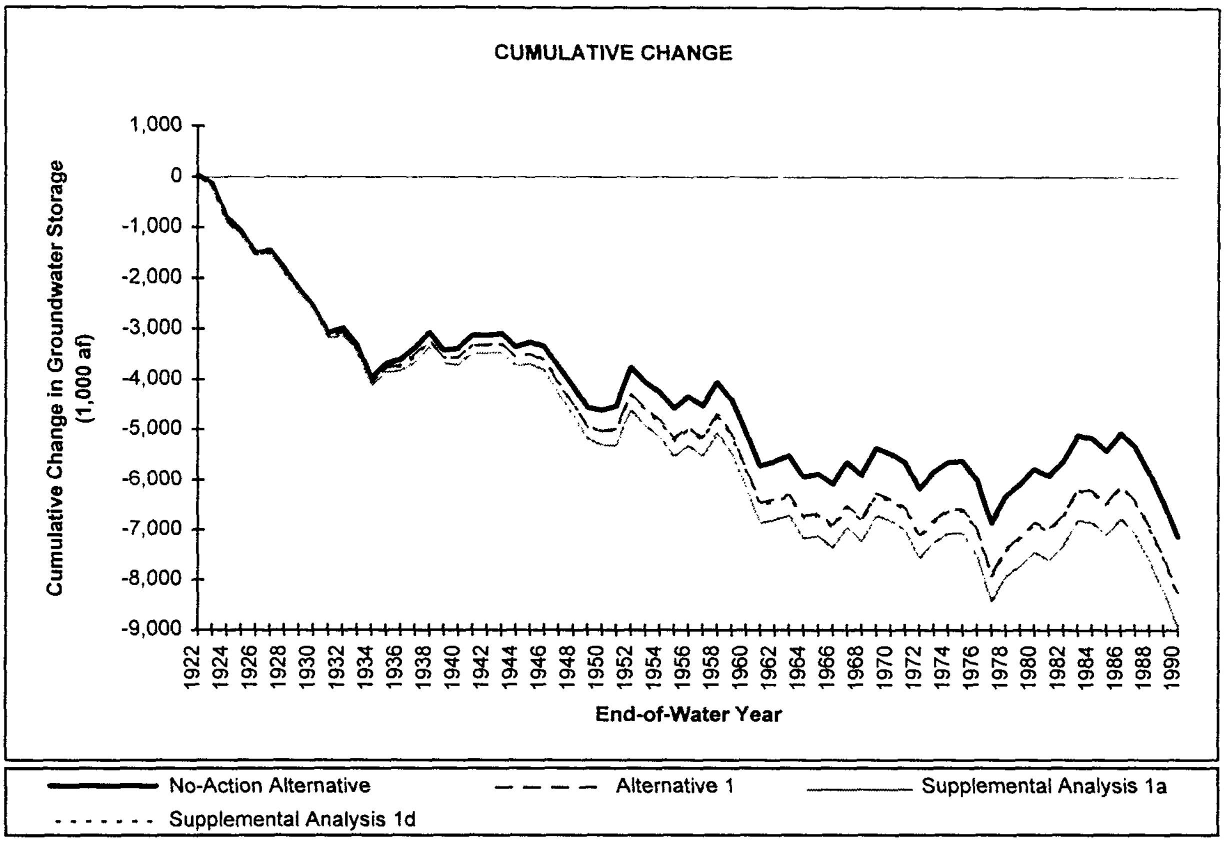

FIGURE B - 107
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR
SUBREGION 15

C—080690

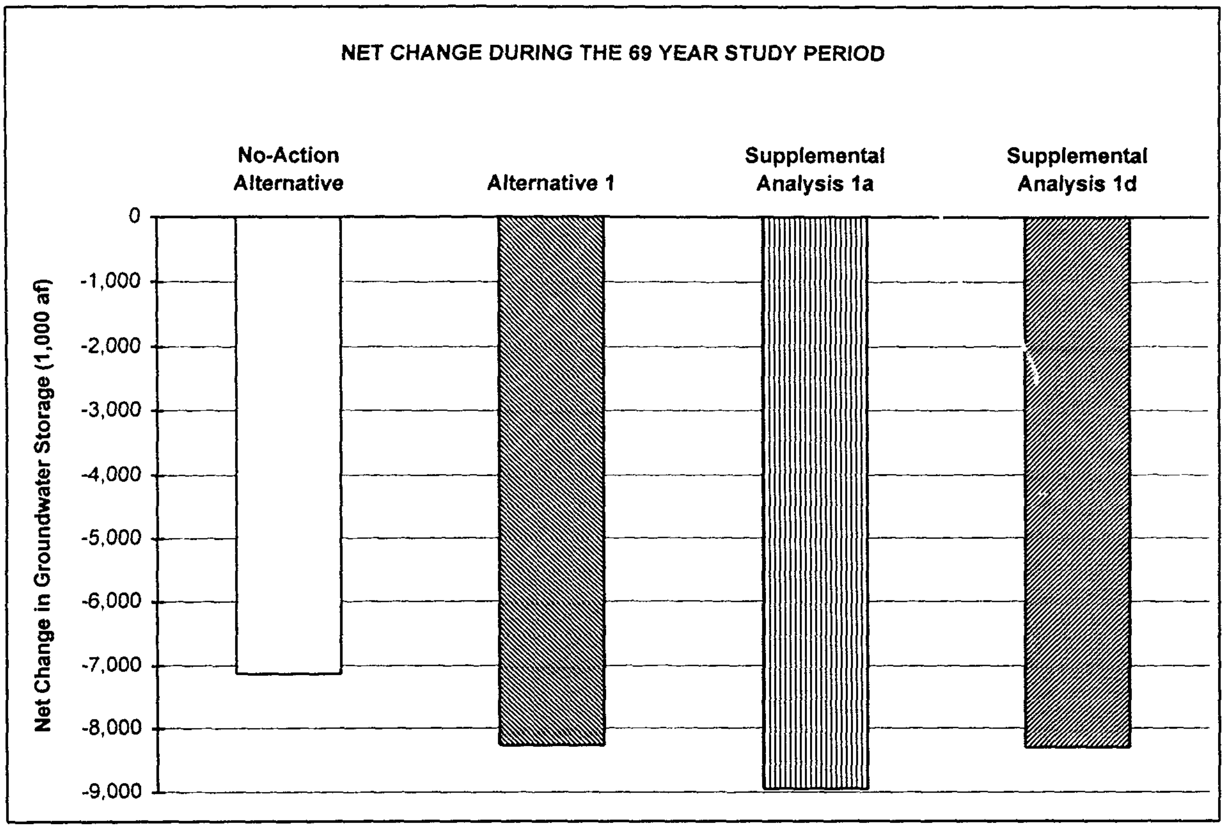

FIGURE B - 108
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 15

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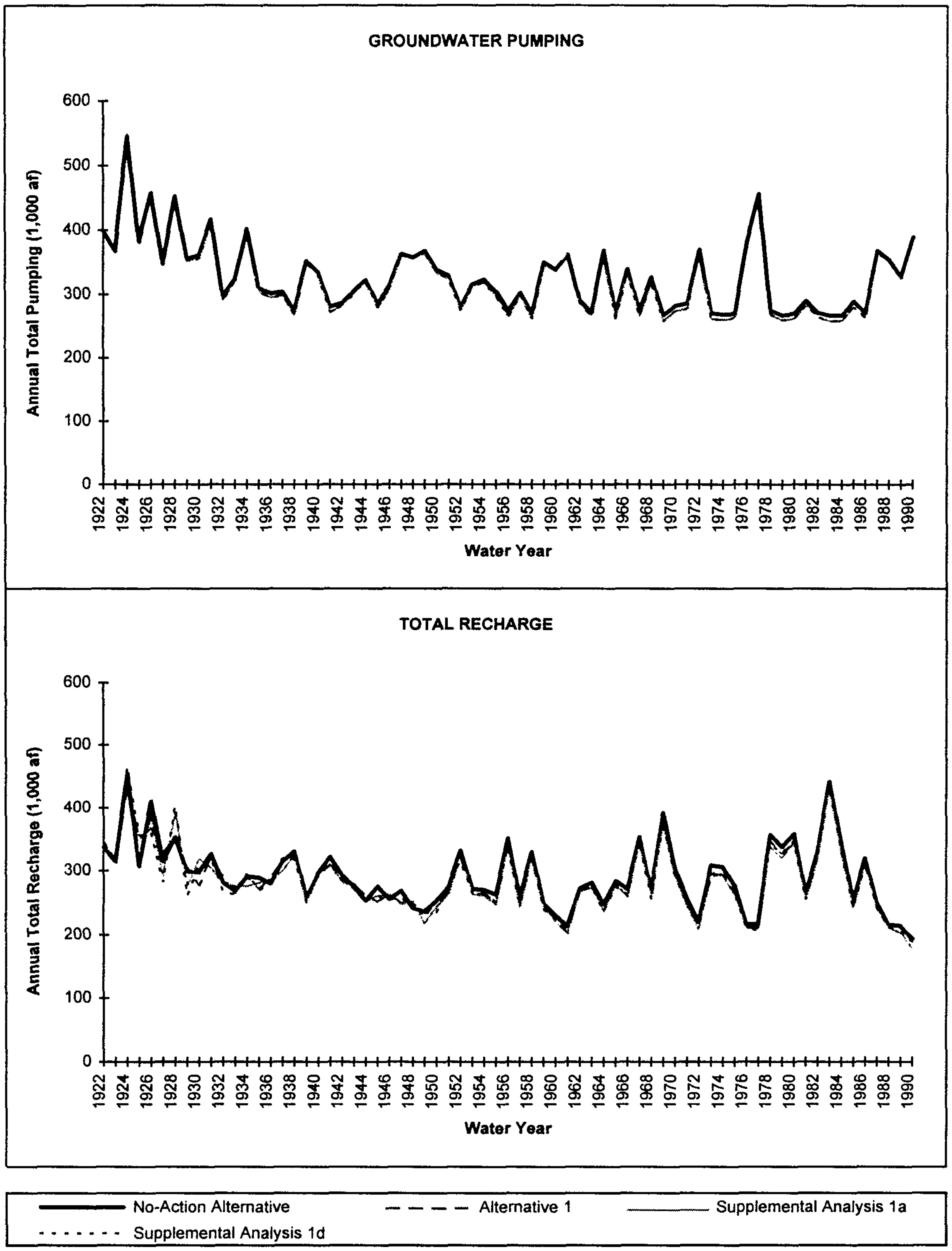

FIGURE B - 109
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 16

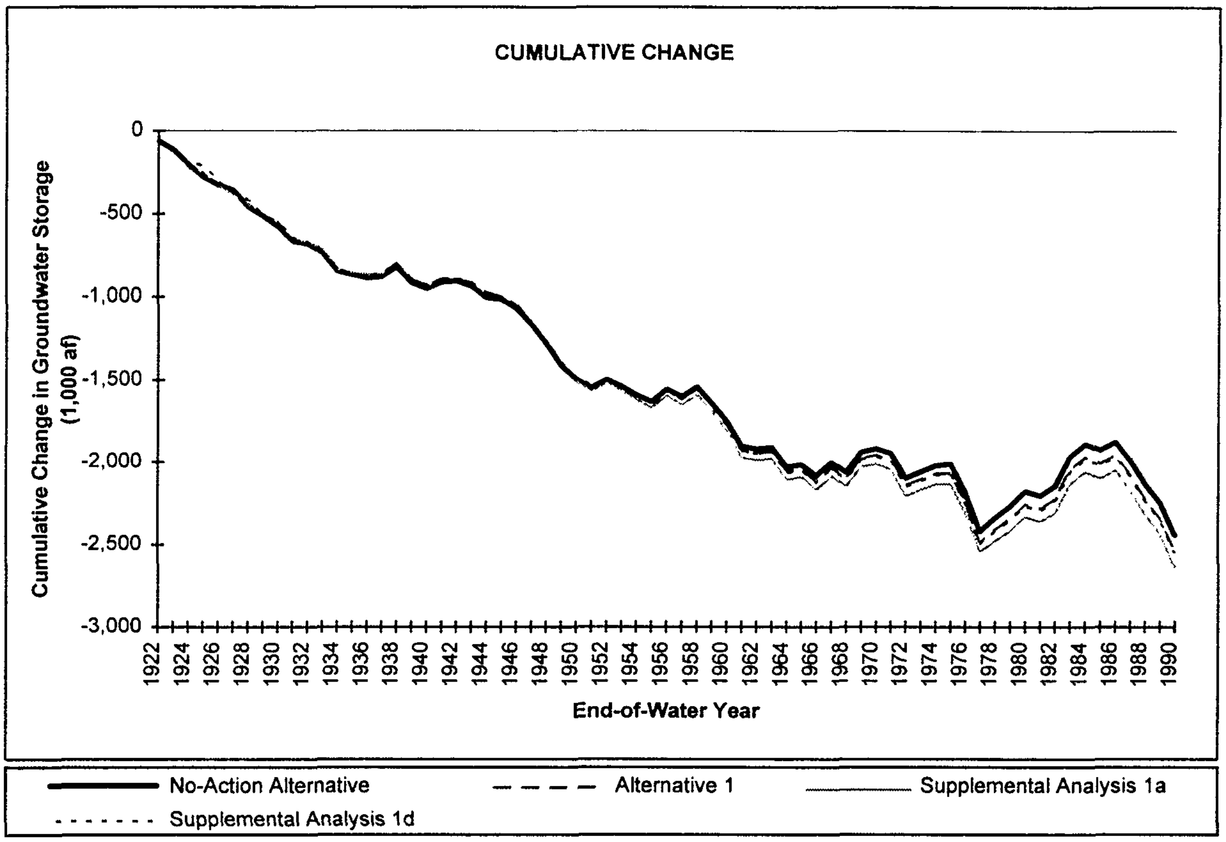

FIGURE B - 110
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 16

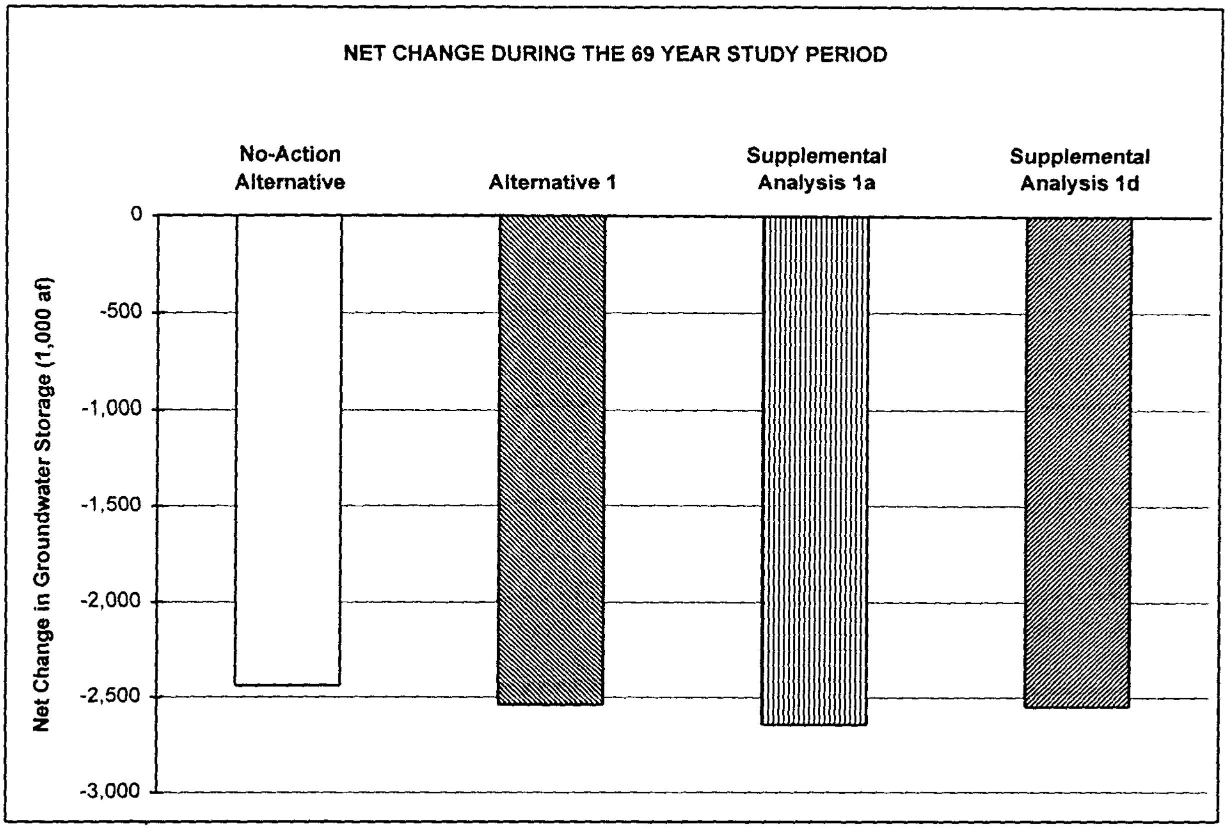

FIGURE B - 111
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 16

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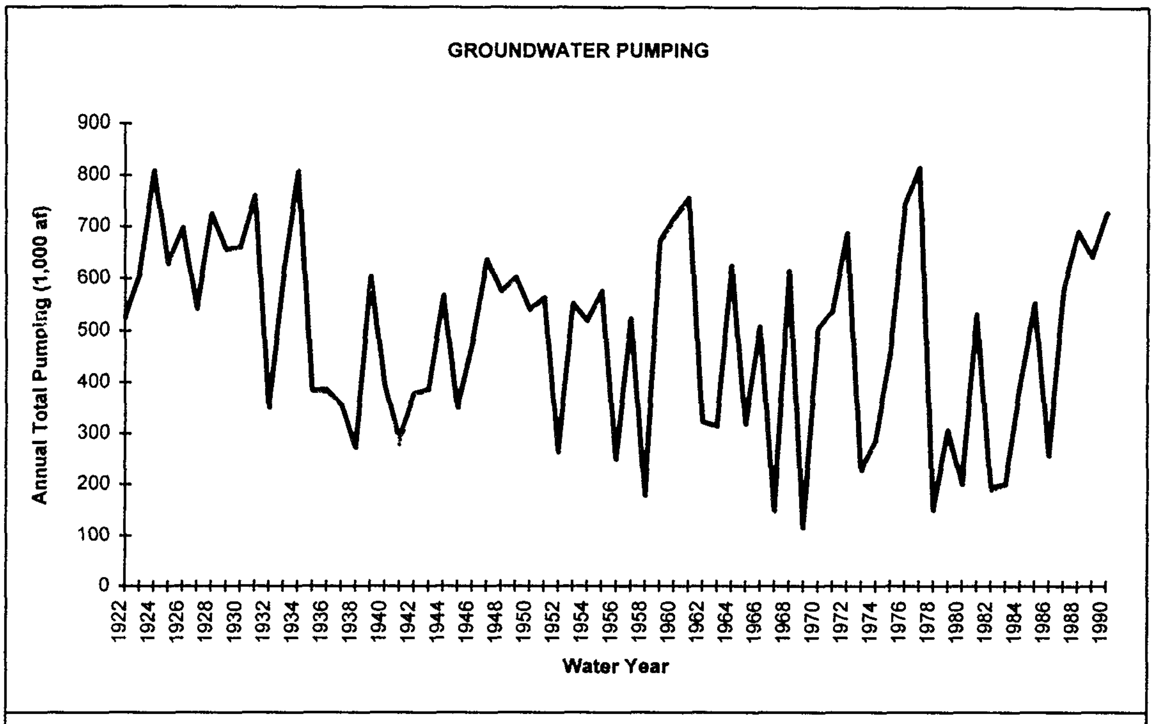

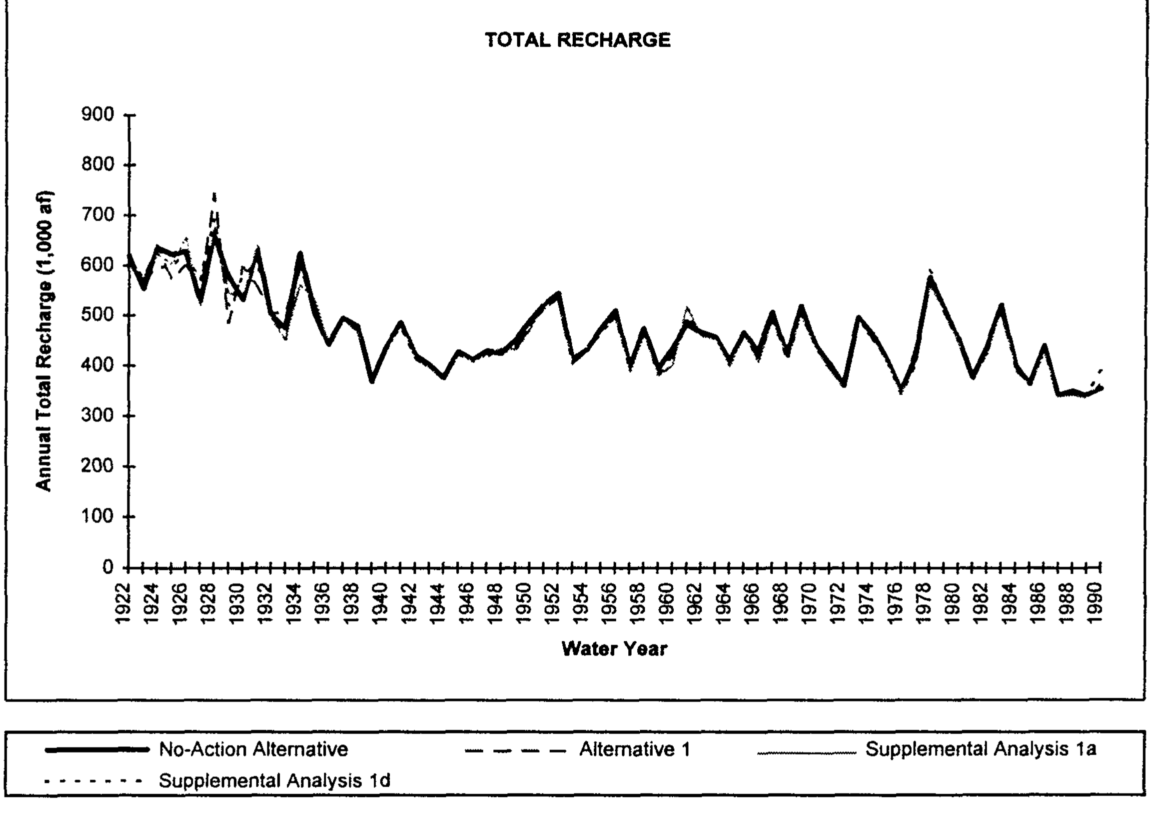

FIGURE B - 112
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 17

C —0 8 0 6 9 7

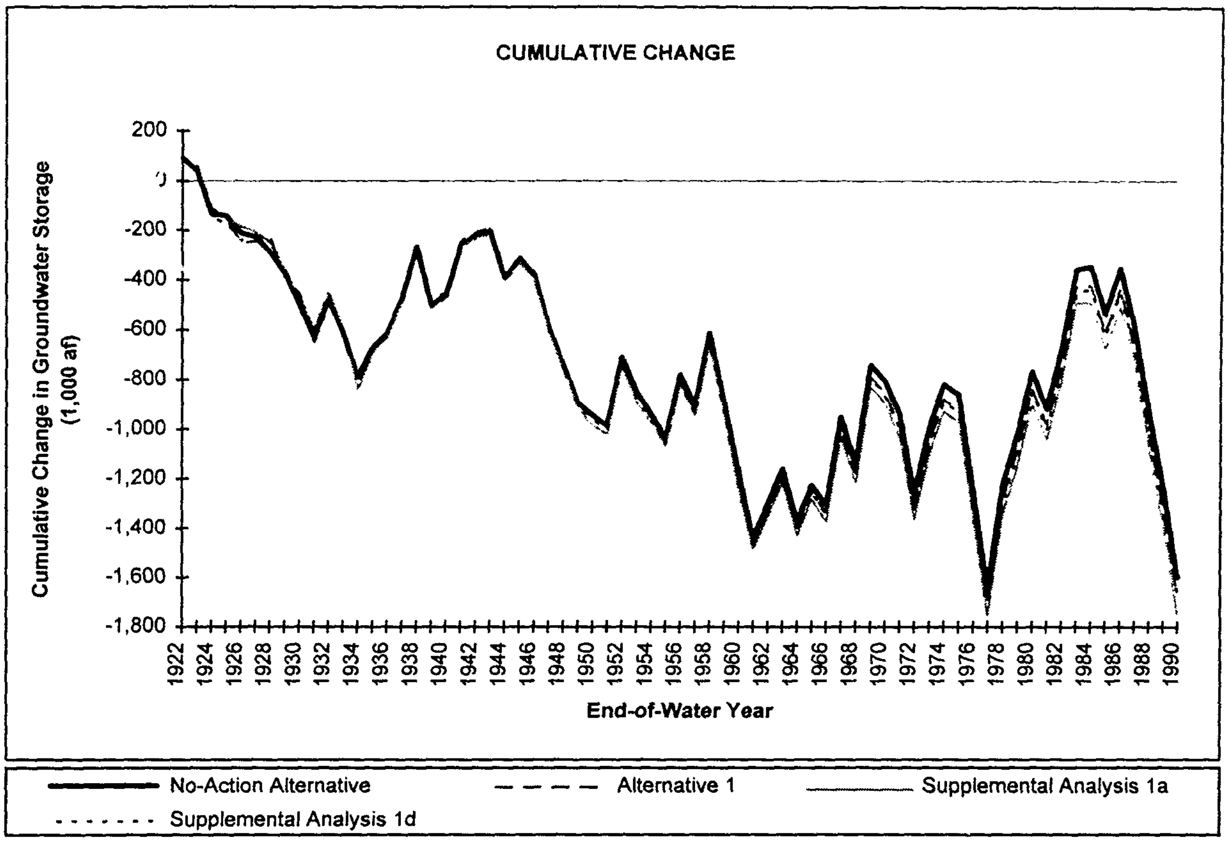

FIGURE B - 113
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 17

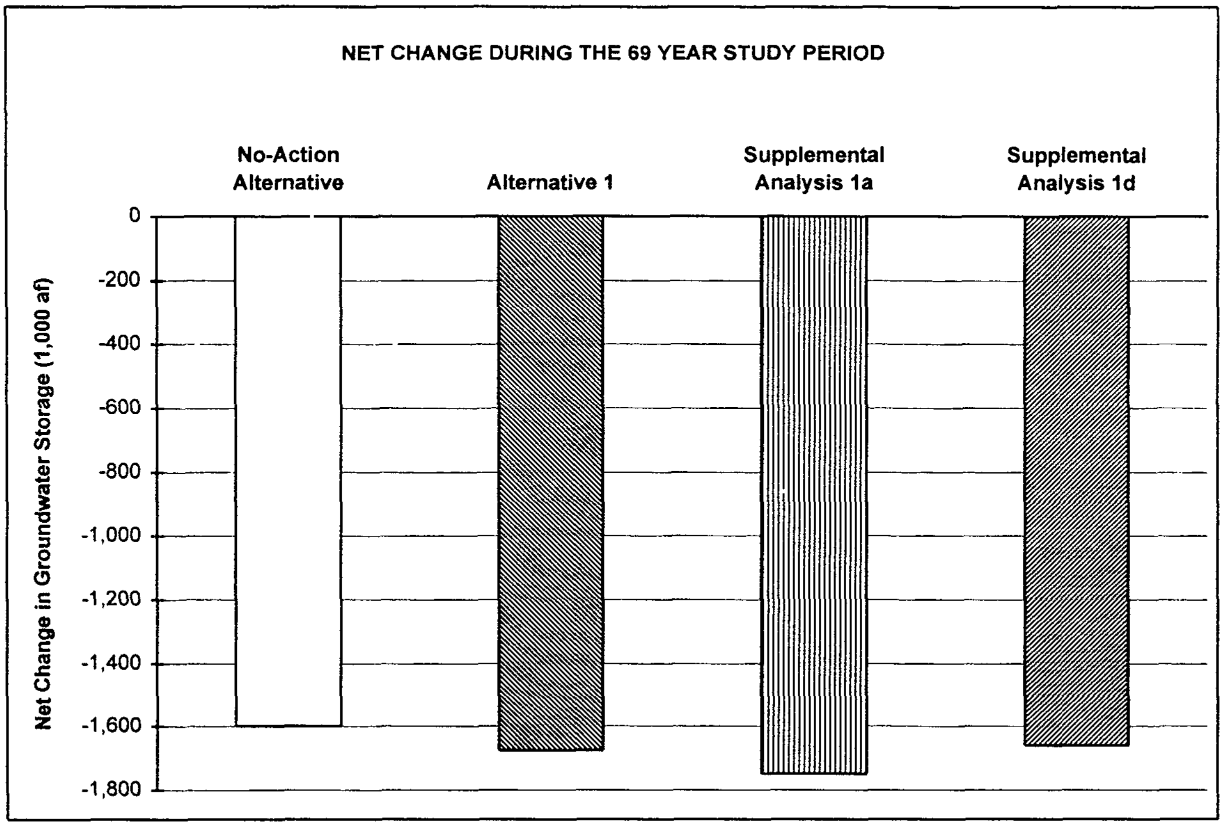

FIGURE B - 114
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 17

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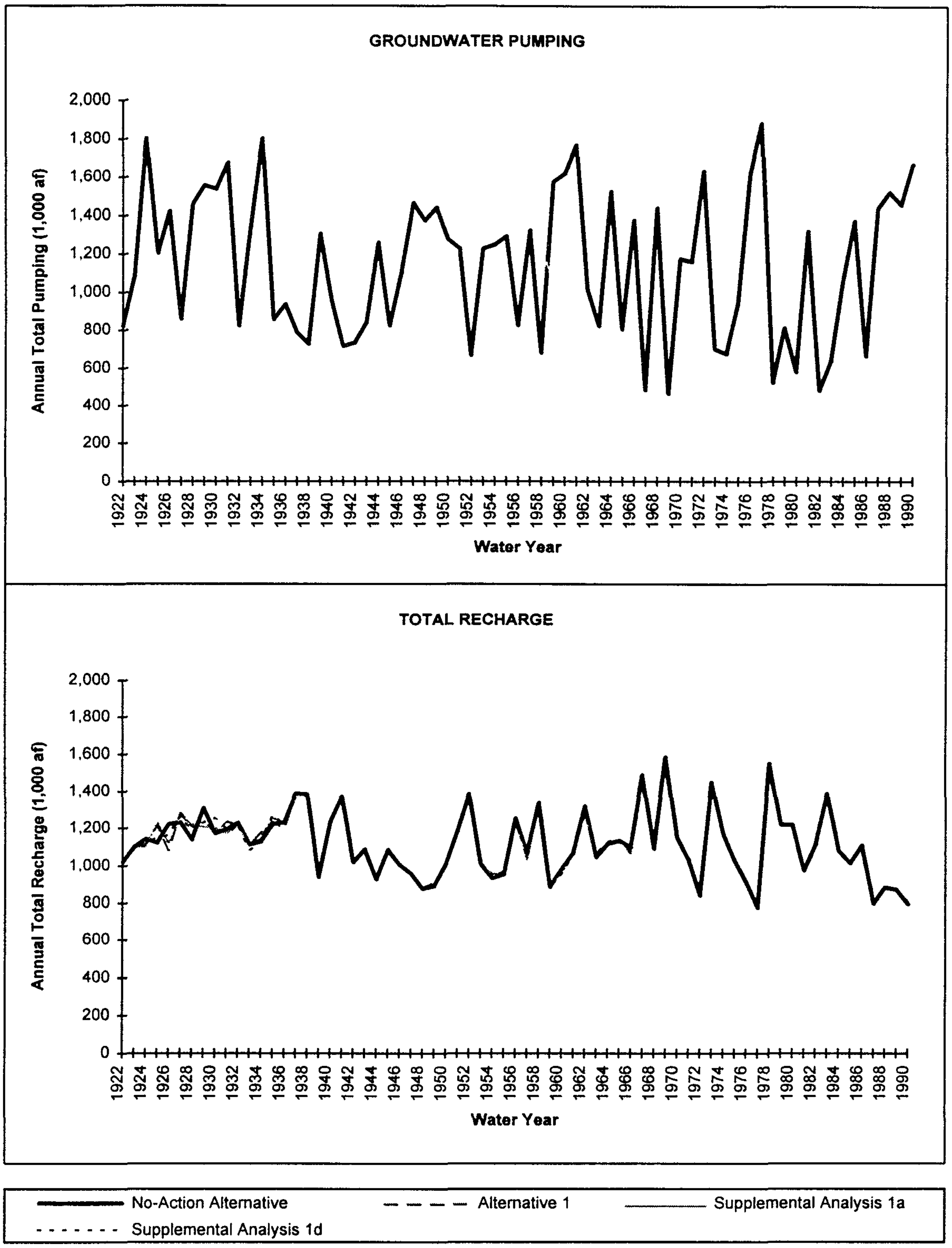

FIGURE B - 115
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 18

C—080701

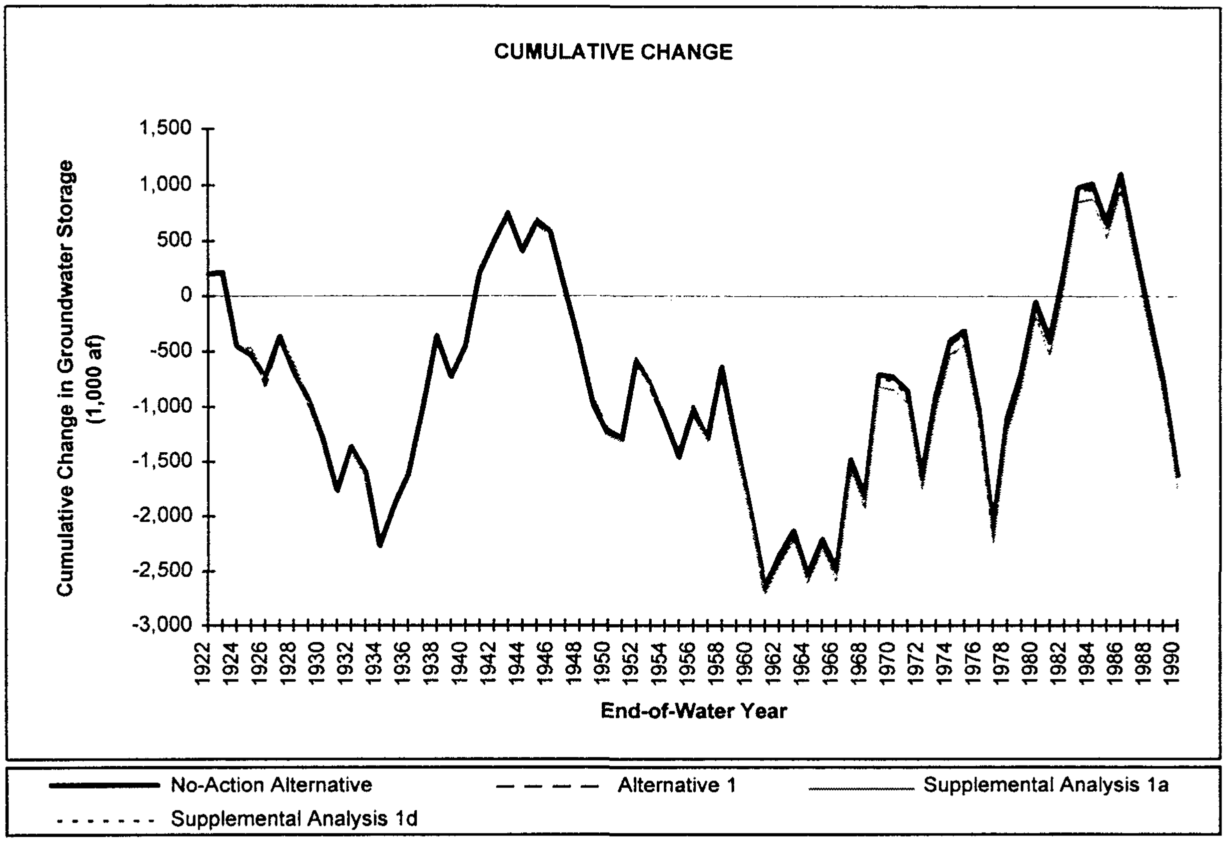

FIGURE B - 116
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 18

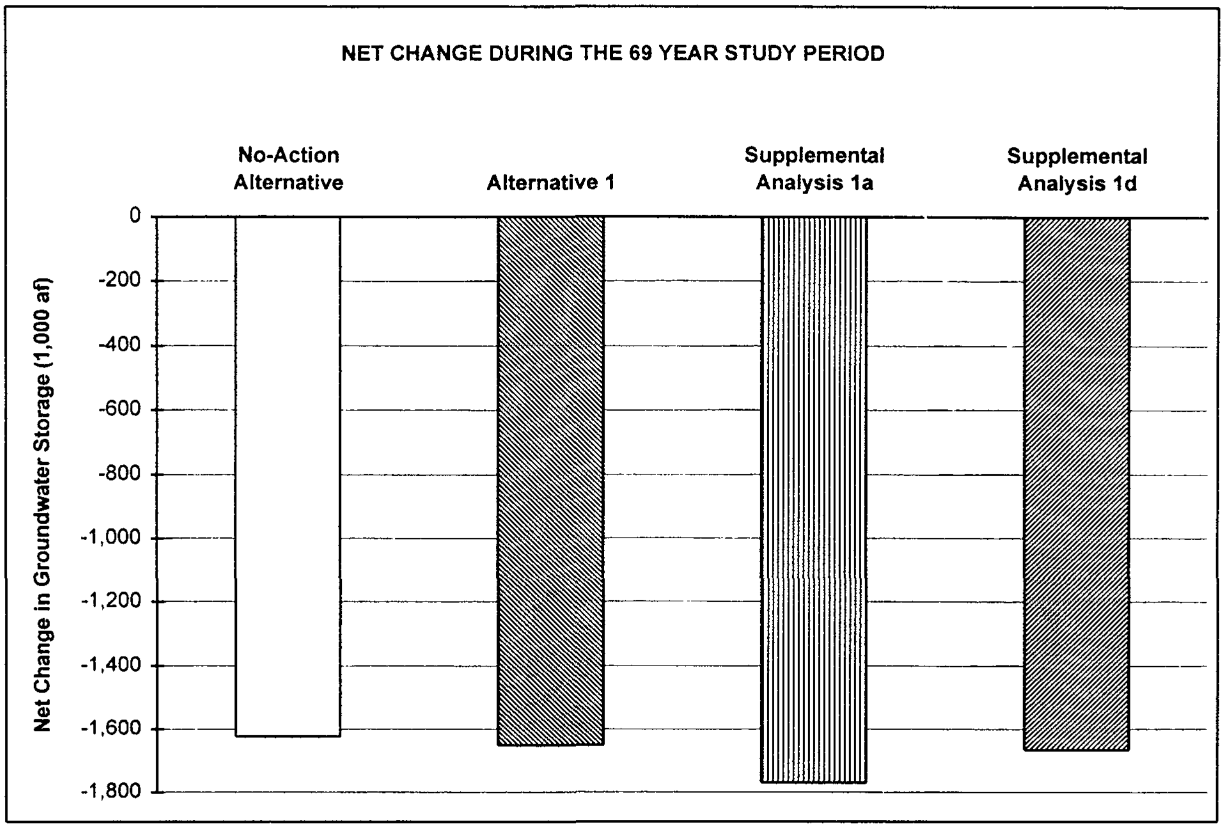

FIGURE B - 117
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 18

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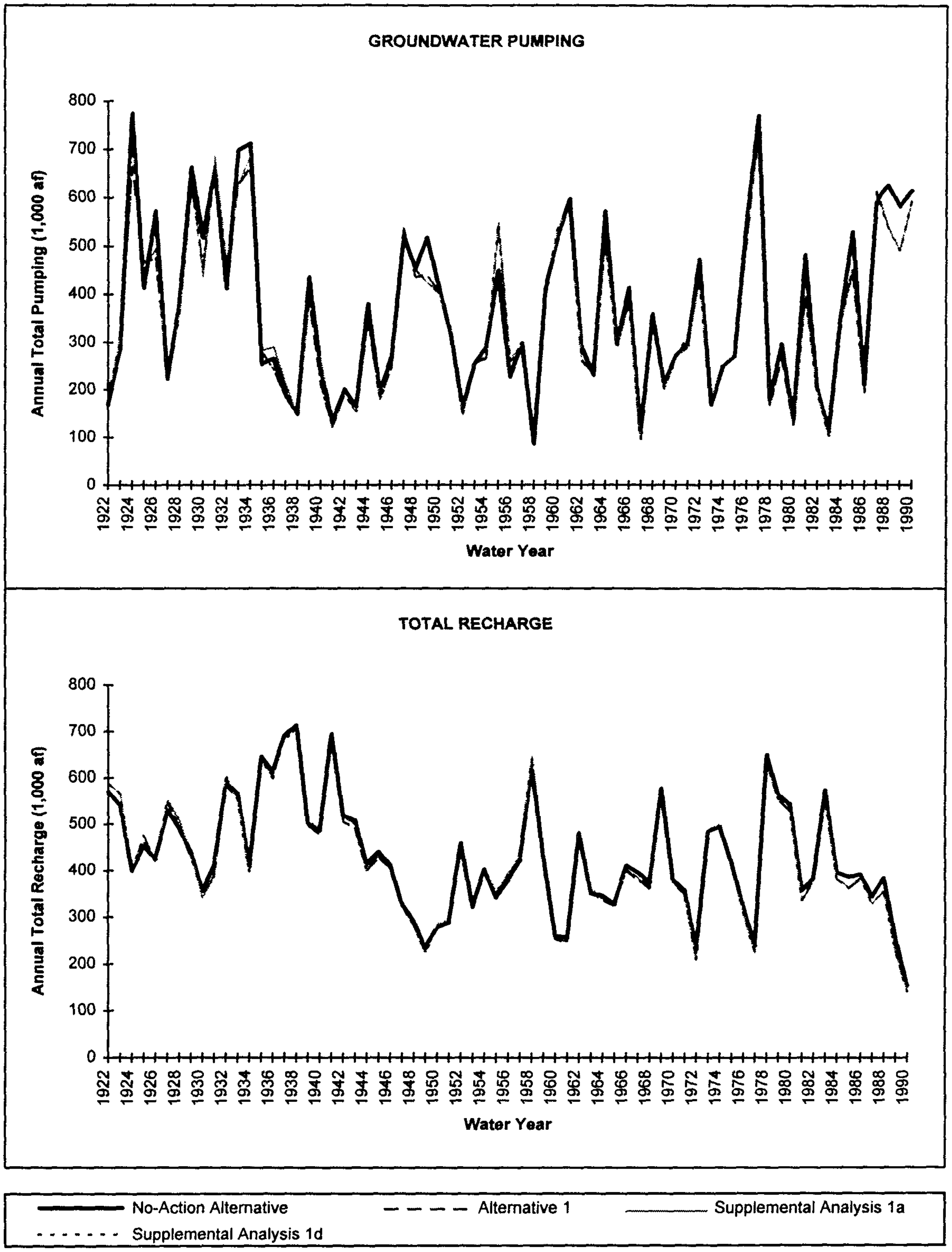

FIGURE B - 118
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 19

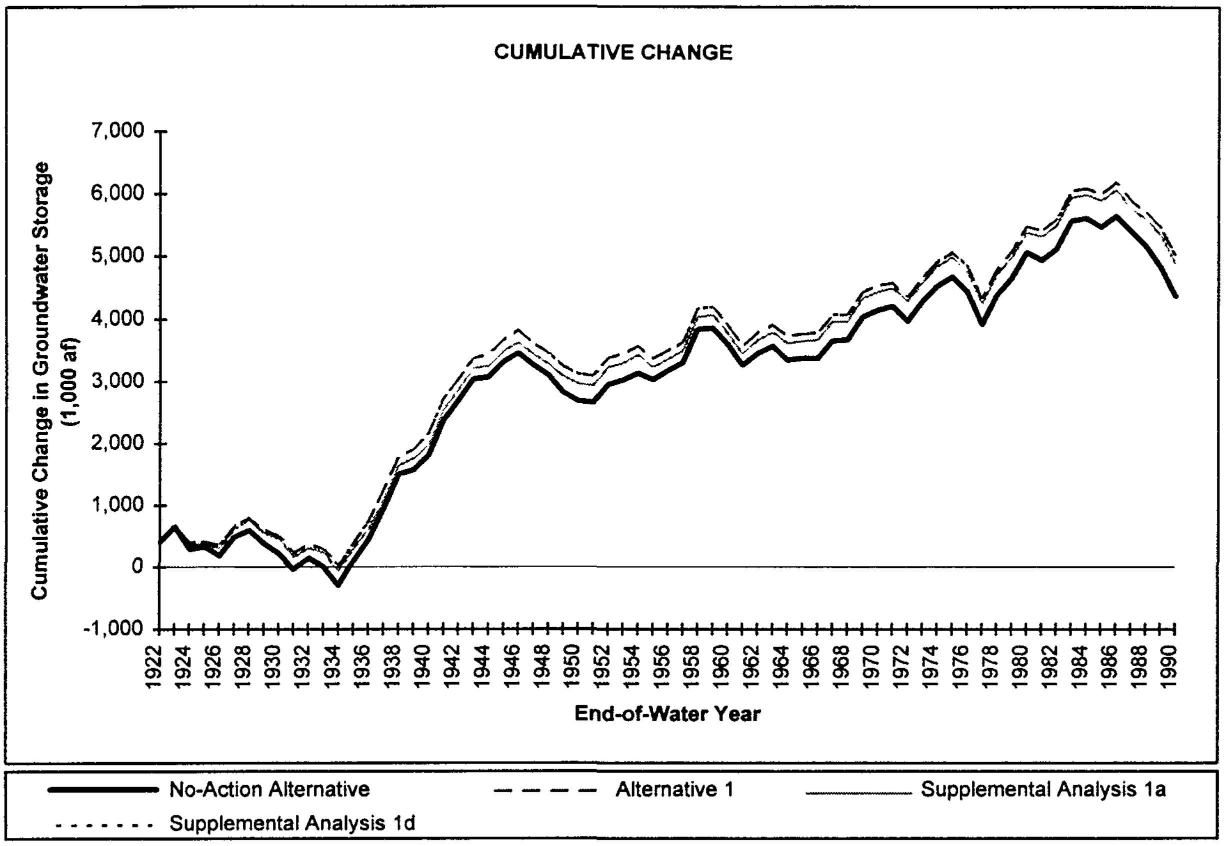

FIGURE B - 119
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 19

C—080706

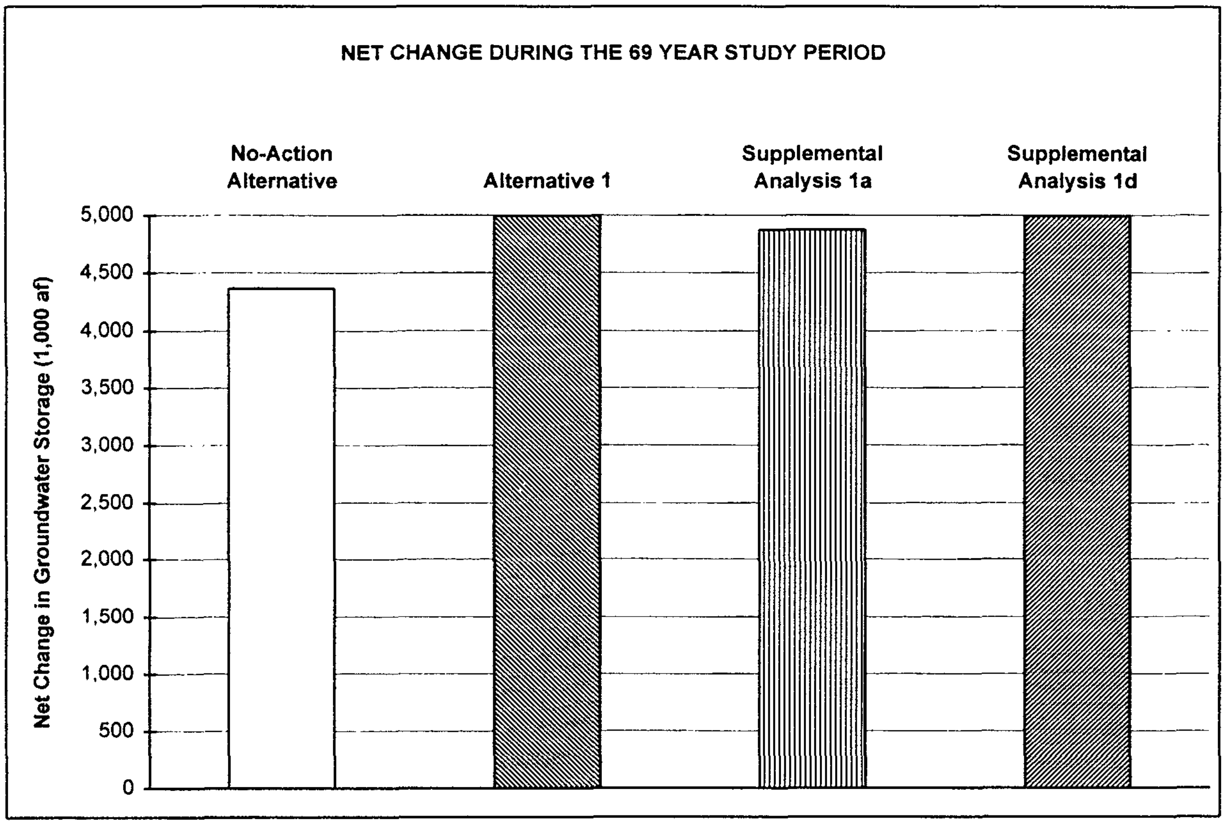

FIGURE B - 120
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 19

C—080707

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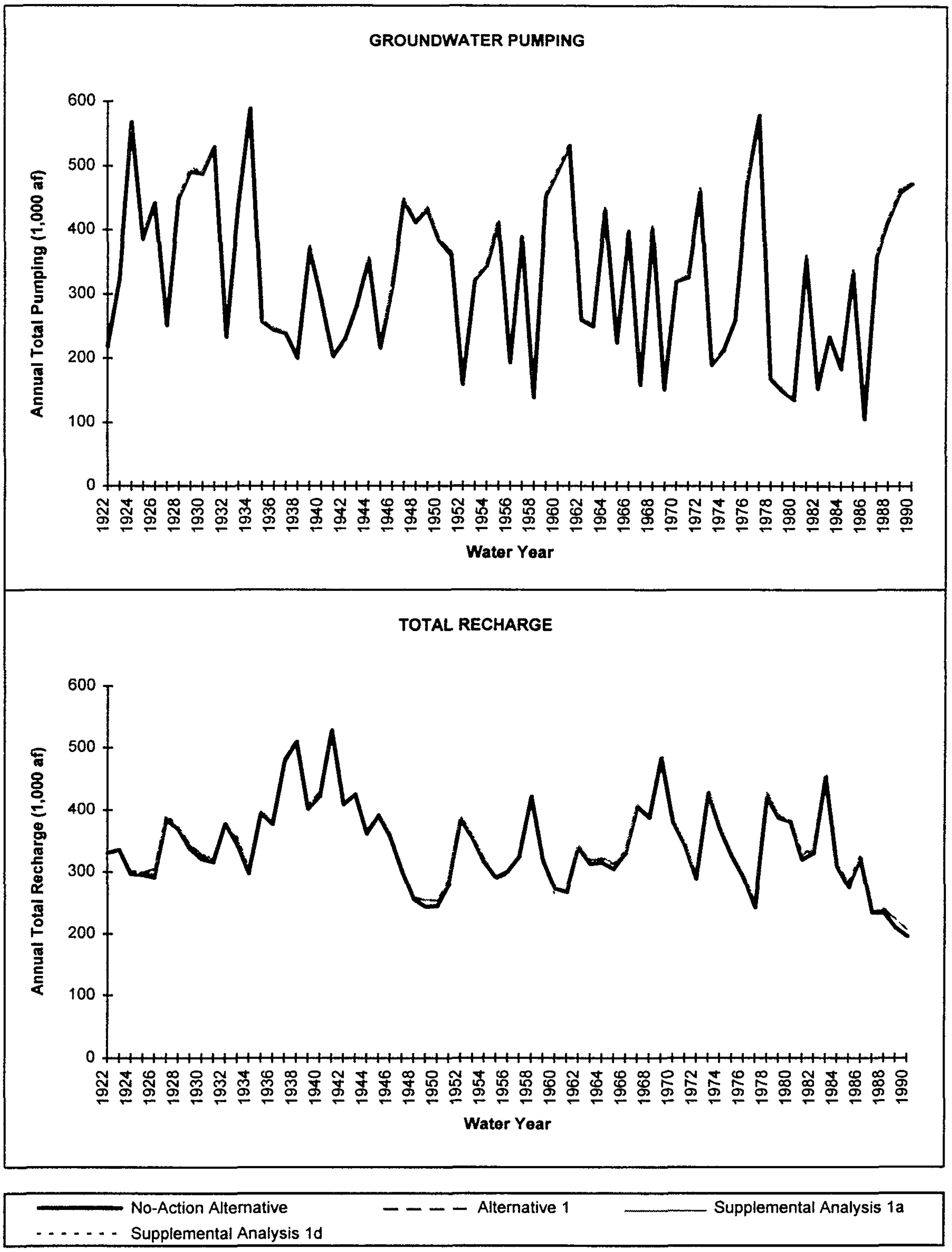

FIGURE B - 121
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 20

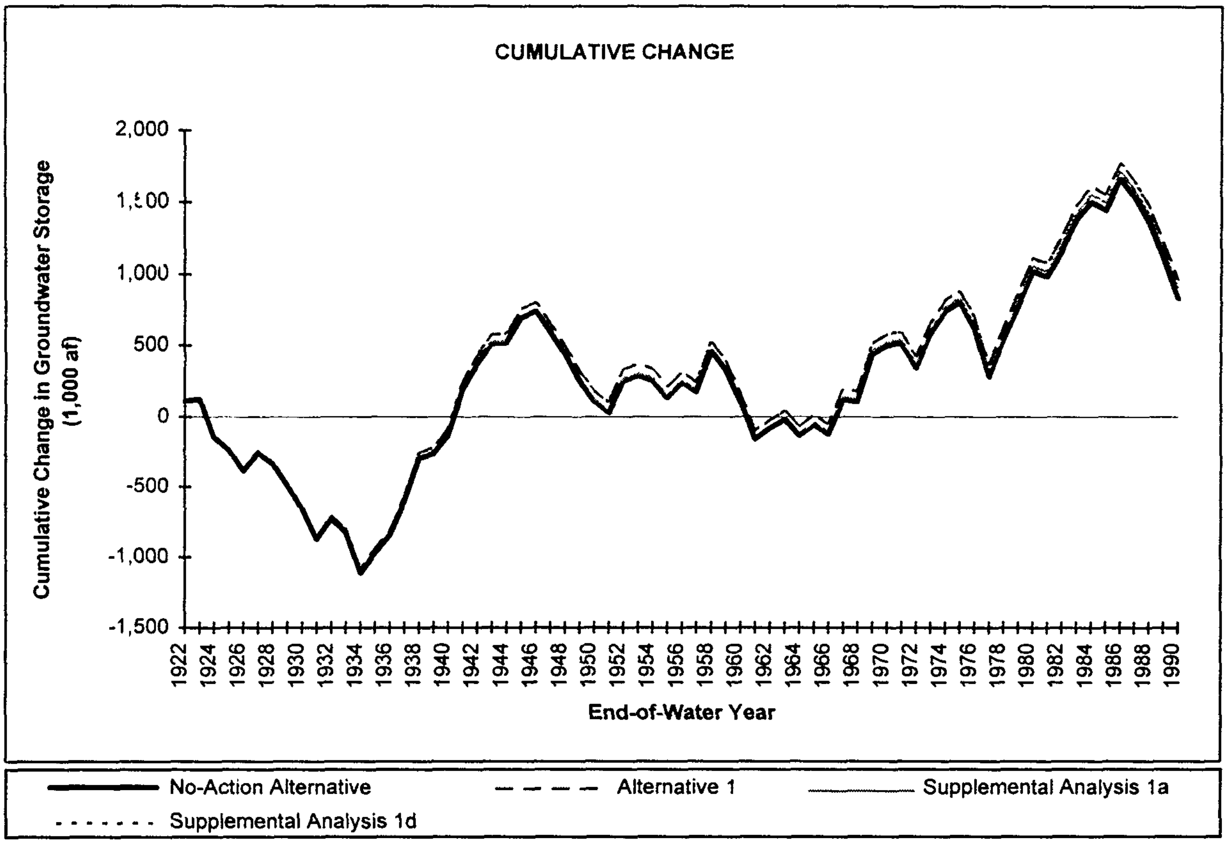

FIGURE B - 122
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 20

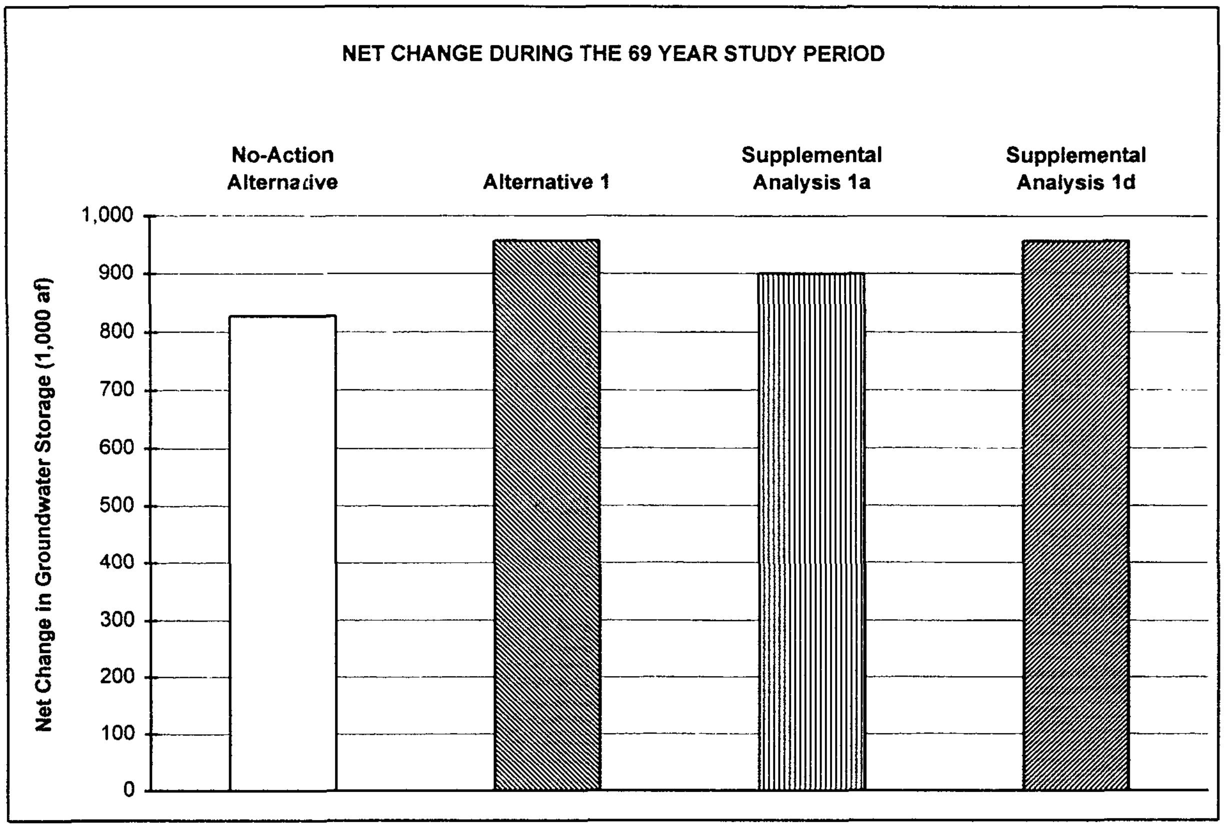

FIGURE B - 123
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 20

C—080711

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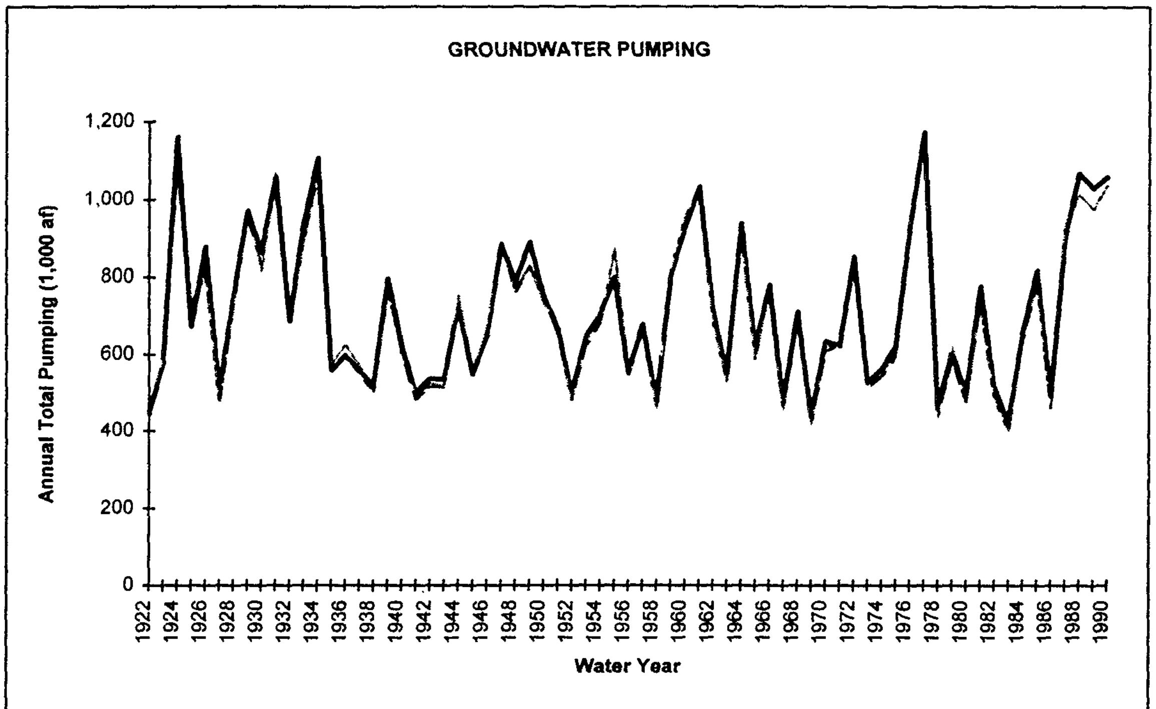

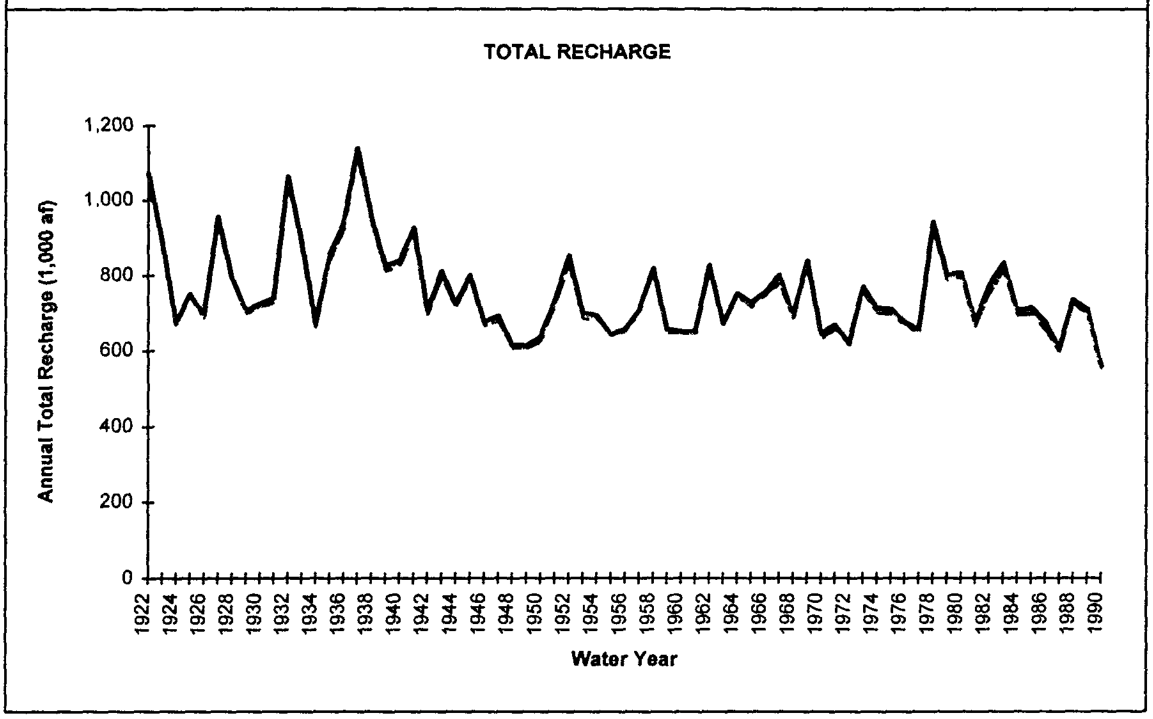

No-Action Alternative — Alternative 1 — Supplemental Analysis 1a — Supplemental Analysis 1d

FIGURE B - 124
SIMULATED GROUNDWATER PUMPING AND RECHARGE FOR SUBREGION 21

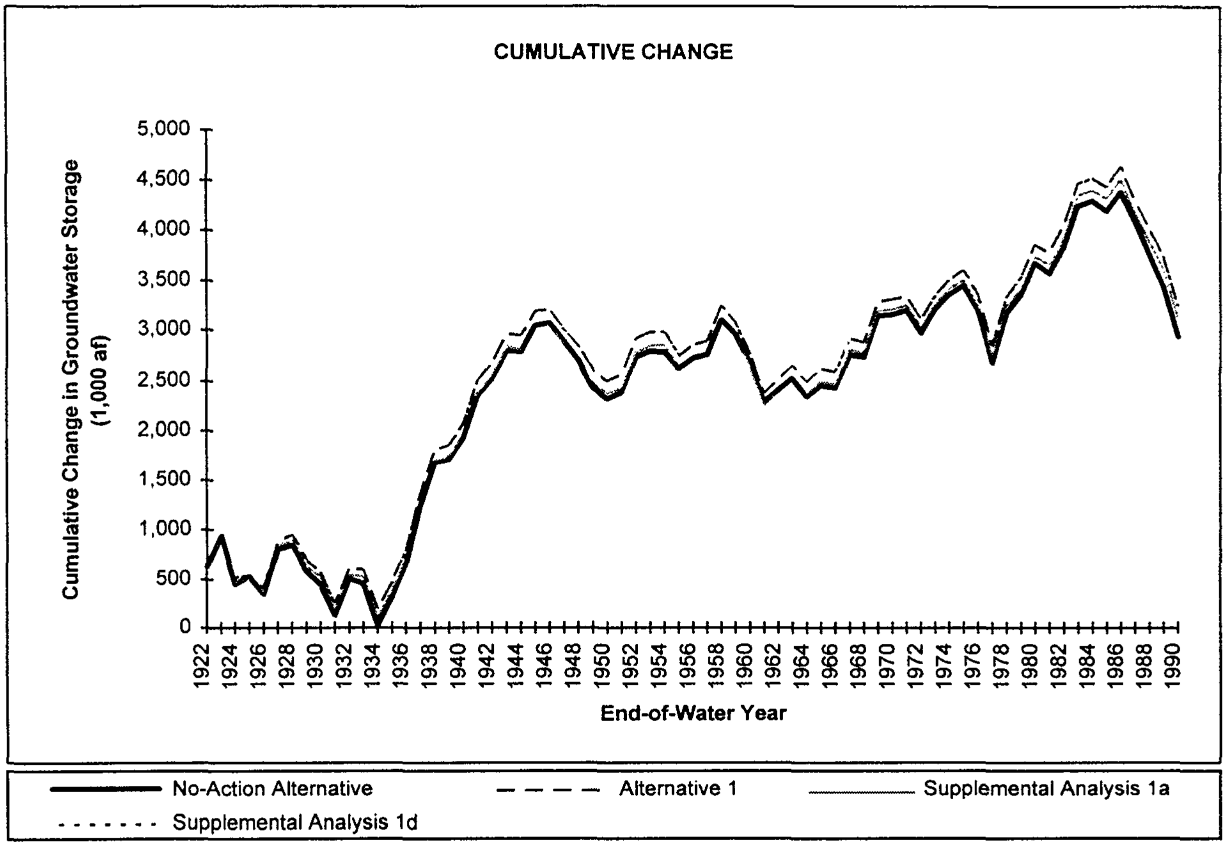

FIGURE B - 125
CUMULATIVE CHANGE IN GROUNDWATER STORAGE FOR SUBREGION 21

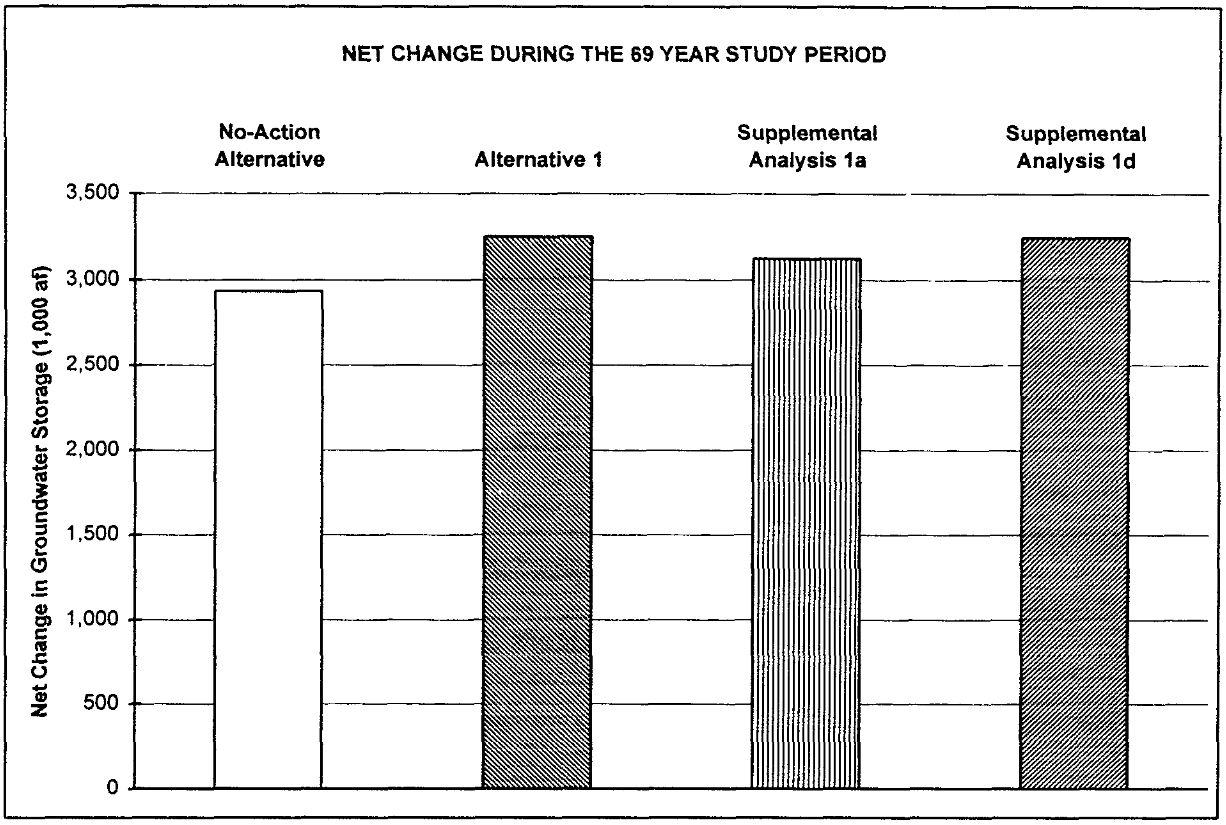

FIGURE B - 126
NET CHANGE IN GROUNDWATER STORAGE DURING THE 69 YEAR SIMULATION PERIOD FOR SUBREGION 21

ATTACHMENT C

DIFFERENCES IN GROUNDWATER MODELING ANALYSIS

C — 0 8 0 7 1 6

MEMORANDUM

Central Valley Project

ENVIRONMENTAL TEAM

To:	John Johannis	Date:	February 19, 1997
From:	Roger Putty	C.C.:	David Moore Gwen Buchholz
Subject:	Meeting with DWR regarding groundwater overdraft		

This memorandum documents the decisions reached during a meeting held between CVPIA PEIS project staff and DWR. The purpose of the meeting was to address DWR comments regarding the reporting of groundwater overdraft in the July 1996 Administrative Draft Groundwater Technical Appendix (GWTA). The decisions were:

1. Change the discussion of groundwater overdraft in the GWTA to a discussion of changes in groundwater storage. In particular, note that the analysis of changes in storage is for the purposes of comparing alternatives to the No-Action Alternative, and the results are not to be interpreted as predictive of future groundwater conditions.

2. Include a discussion in the GWTA listing the primary differences between Bulletin 160-93 and the GWTA that would influence the outcome of the groundwater analysis presented in the two documents. This is not meant to be a comprehensive listing of ALL differences between 160-93 and PEIS assumptions; it is only addressing MAJOR differences, in a verbal format, that would contribute to differences in the outcome of the groundwater analysis.

A listing of the general differences between Bulletin 160-93 and the GWTA is attached. Please review and provide comments at your earliest convenience.

DIFFERENCES BETWEEN BULLETIN 160-93 AND THE GWTA

Provided below is a listing of primary differences between DWRs Bulletin 160-93 and the CVPIA PEIS Groundwater Technical Appendix (GWTA). The listing is limited to those items that contribute to differences in groundwater conditions reported in the two documents.

1. Bulletin 160-93 reports predictive groundwater information for projected-level conditions for purposes of future water supply planning. The GWTA reports groundwater conditions with the intent of providing a relative measure of groundwater impacts associated with the PEIS alternatives in comparison to the No-Action Alternative. References or conclusions in the GWTA are not based on absolute values of the No-Action Alternative or the PEIS alternatives.

2. The methodology used to evaluate groundwater conditions are different between the two reports. Bulletin 160-93 evaluated groundwater conditions using a water balance approach based on normalized average hydrologic conditions for the historic period 1970 through 1983, and normalized average demands for projected-level land use conditions. The GWTA infers changes in groundwater conditions using results from an integrated groundwater-surface water simulation model. This approach incorporates variable hydrologic conditions based on the historic period 1922 through 1990, and variable demands based on fixed projected-level land use conditions and variable climatic conditions. An important consideration of these different methods is the handling of groundwater recharge. The water balance approach depends on a long-term average recharge to the groundwater basin. The simulation model determines the recharge dynamically as the groundwater basin changes over the monthly simulation period, resulting in varied recharge conditions depending upon the factors represented in the model.

3. With regards to the analysis of groundwater conditions, some differences in region boundaries exist between Bulletin 160-93 and the GWTA. A summary the differences by region consist of:
   - Sacramento River Region: The GWTA definition includes southern Sacramento County, San Joaquin County, and eastern Contra Costa County. These areas are not included in DWRs definition of the Sacramento River Region

   - San Joaquin River Region: The GWTA definition does not include southern Sacramento County, San Joaquin County, or eastern Contra Costa County. These areas are included in DWRs definition of the San Joaquin River Region.

   - Tulare Lake Region: The geographic definition of the Tulare Lake Region in the GWTA are comparable to the definition used in Bulletin 160-93.

4. Bulletin 160-93 relies on projected-level land use conditions as a basis for determining future groundwater conditions. The 2020 projected-level land use conditions reported by Bulletin 160-93 are used initially in the hydrologic and economic modeling analysis of the PEIS No-Action Alternative. Based on simulated No-Action Alternative water supply and groundwater conditions, and associated policy assumptions, the agricultural production model calculates

2020 projected-level land use conditions (crop acreage and crop mix). This land use condition serves as the basis for the No-Action Alternative groundwater analysis for the GWTA.

5. The Bulletin 160-93 incorporates Decision 1485 into its analysis of future supplies. The PEIS No-Action Alternative incorporates the December 1995 Bay-Delta Plan Accord.

6. Groundwater pumping reported by region in Bulletin 160-93 is for Net Use of Groundwater (defined as the total groundwater pumping minus deep percolation of applied water). Groundwater pumping in the GWTA is reported as total groundwater pumping for the No-Action Alternative.

7. Groundwater overdraft reported in DWR Bulletin 160-93 includes estimates of groundwater storage lost due to groundwater quality degradation. The changes in storage reported in the CVPIA PEIS only include physical changes in storage as a result of groundwater withdrawal in excess of recharge. Groundwater quality degradation in the CVPIA PEIS is assessed qualitatively only, and considers the possible migration of poor quality groundwater in response to changes in regional groundwater levels.

CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT TECHNICAL APPENDIX

CVP Power Resources

September 1997

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C-080723

LIST OF TABLES

LIST OF FIGURES

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LIST OF ABBREVIATIONS AND ACRONYMS

Contract 2948A	Contract No. 14-06-200-2948A
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
GWh	gigawatt-hours
kW	kilowatt
LCC	Load Carrying Capability or Capacity supported with energy
MW	megawatts
PEIS	Programmatic Environmental Impact Statement
PG&E	Pacific Gas and Electric Company
PROSIM	Hydrologic Project Simulation Model used by Reclamation
PROSYM	Electric System Production Cost Model
Reclamation	U.S. Bureau of Reclamation
SANJASM	San Joaquin Area Simulation Model
Service	U.S. Fish and Wildlife Service
SNR	Sierra Nevada Region of Western Area Power Administration
SWP	California State Water Project
SWRCB	California State Water Resource Control Board
Western	Western Area Power Administration
b(2)	Refers to water dedicated under Section 3406(b)(2)

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Draft Programmatic Environmental Impact Statement (PEIS) summarizes the evaluation of the direct and indirect impacts of implementing a wide range of actions identified in the Central Valley Project Improvement Act (CVPIA). Details of the information used in the definition of the affected environment and analysis of the environmental consequences are presented in the technical appendices of the Draft PEIS.

This technical appendix presents a summary of CVP power resources background information that was used during the PEIS preparation, and the results of the impact analyses for conditions that occurred in the CVP service area.

The CVP power resources analysis was primarily based upon changes in CVP operations that may lead to changes in reservoir storage levels, reservoir release patterns, and pumping patterns. Information from the Surface Water and Facilities Operations Technical Appendix and from Western Area Power Administration analyses were used in the CVP power resource analyses.

The assumptions and results of the analyses for Alternatives 1, 2, 3, and 4 are presented in this technical appendix and summarized in the Draft PEIS. The assumptions and results of the analyses for Supplemental Analyses 1a through 1i, 2a through 2d, 3a, and 4a are summarized only in the Draft PEIS. The assumptions related to the CVP power resources analyses for Alternatives 1, 2, 3, and 4 are presented in Table I-1. The results of the analyses are presented in Table I-2.

TABLE I-1

SUMMARY OF ASSUMPTIONS FOR CVP POWER RESOURCES

Assumptions Common to All Alternatives or Supplemental Analyses
CVP Generation Contract 2948A with PG&E would not be renewed. Shasta Temperature Control Device in operation. CVP power generation incidental to water operations.
CVP Project Use Project Use load met at all times. On and off-peak definitions per 2948A.
CVP Market Value of Power Energy available for sale based on long term (1922 - 1990) average. Capacity available for sale based on 90 percent exceedence synthetic dry year. Reservoir operation and project use based on Surface Water Supplies and Facilities Operations analyses.

TABLE I-2

SUMMARY OF IMPACT ASSESSMENT OF CVP POWER RESOURCES

Affected Factors	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
		Change from No-Action Alternative			
CVP Generation					
Average Annual (GWh/yr)	4,935	-5.4%	-5.2%	-5.3%	-5.1%
Average Annual Dry Period (1929-1934) (GWh/yr)	2,764	-5.0%	-4.7%	-5.3%	-4.9%
Average Monthly Available Capacity (MW)	1,597	-1.4%	-1.4%	-1.3%	-1.6%
Average Monthly Dry Period (1929-1934) Available Capacity (MW)	1,380	-4.7%	-4.8%	-4.9%	4.8%
CVP Project Use					
Average Annual (GWh/yr)	1,425	-10.3%	-10.2%	-4.0%	-11.3%
Average Annual Dry Period (1929-1934) (GWh/yr)	974	-10.7%	-10.6%	1.6%	-11.5%
Average Monthly On Peak Capacity (MW)	184	-8.1%	-7.9%	-2.8%	-10.0%
Average Monthly Dry Period (1929-1934) On Peak Capacity (MW)	142	-8.9%	-9.3%	0.2%	-9.9%
Market Value of Power					
Average Annual Energy Available for Sale (GWh/yr)	3,511	-3.4%	-3.2%	-5.8%	-2.6%
Average Monthly Capacity with Energy for Sale (90% exceedence synthetic dry year)	756	6.0%	2.8%	3.2%	2.6%
Average Monthly Capacity without Energy for Sale (90% exceedence synthetic dry year)	708	-12.1%	-8.4%	-13.7%	-15.9%
Average Annual Change in Market Value	$125,800,000	$100,000	-$1,100,000	-$2,800,000	-$1,800,000

CHAPTER II

AFFECTED ENVIRONMENT

Chapter II

AFFECTED ENVIRONMENT

LEGISLATIVE AUTHORIZATIONS

Central Valley Project (CVP) facilities were constructed and are operated under Reclamation Law and the authorizing legislation for each facility. Initially, Reclamation projects were authorized under the Reclamation Act of 1902. The Act of 1902 authorized projects to be developed solely for irrigation and reclamation purposes.

In 1906, Reclamation Law was amended to include power as a purpose of the projects if power was necessary for operation of the irrigation water supply facilities, or if power could be developed economically in conjunction with the water supply projects. The Act of 1906 allowed for lease of surplus power. Surplus power was described as power that exceeds the capacity and energy required to operate the Reclamation facilities (Project Use Load). The Act of 1906 stipulated that surplus power would be leased with preference for municipal purposes.

Power supply was first authorized as a purpose for some CVP facilities in the Rivers and Harbors Act of 1937 that included authorization for federal funding of the initial CVP facilities. The Act of 1937 defined the priorities for the purposes of the CVP as: 1) navigation and flood control, 2) irrigation and municipal and industrial water supplies, and 3) power supply.

The Reclamation Project Act of 1939 modified Reclamation Law for all Reclamation facilities, including the CVP. This act changed the maximum term of Reclamation's water supply and power contracts to a period of 40 years, reconfirmed the preference clause, and included the policy that the federal government would market power to serve the public interest rather than to obtain a profit. The Act of 1939 changed the methodology of calculation of interest rates to be applied to surplus power contracts.

Until 1977, Reclamation operated the CVP power generation and transmission facilities and marketed the power generated by the CVP facilities. In 1977, Western Area Power Administration (Western) was established as part of the Department of Energy. Western operates, maintains, and upgrades the transmission grid that was constructed by the CVP. Western, as part of their marketing function, ensures that CVP Project Use loads are met at all times by using a mix of generation resources including CVP generation and other purchased resources. Western also dispatches and markets power surplus to the CVP project needs to Preference Power Customers and other utilities.

CENTRAL VALLEY PROJECT HYDROELECTRIC GENERATION FACILITIES

The CVP hydroelectric facilities are part of the large multipurpose project encompassing such areas as power production, flood control, irrigation water supply, municipal and industrial water supply, fish and wildlife, water quality, wetlands maintenance, navigation, and recreation. The major driving factors in powerplant operation are the required downstream water releases, the electric system needs, and Project Use demand. The CVP power facilities include 11 hydroelectric powerplants with 38 generators and have a total maximum generating capacity of 2,045 mega-watts (MW) as schematically presented in Figure II-1. The CVP powerplants have produced an average of 4.8 million kilowatt-hours per year (kWh/year) over the last 15 years.

Revenue from CVP power generation is vital to project repayment and operation and maintenance expenses. Power revenues from the sales of Reclamation's surplus power are used, through appropriations, to cover annual:

- power operation and maintenance expenses
- administrative and general expenses allocated to power
- power equipment replacement expenses
- interest on power investment
- federal power investment expenses
- depreciation

With the ability to support the Central and Northern California power system and the power system reliability, the CVP powerplants have a major long-term role with important implications in California and thus the Nation's security, energy self-sufficiency, quality of life, environment and economy. In addition to providing peaking generation to the Central and Northern California power system, it supplies many secondary benefits to the power system including VAR (magnetic or inductive power) support, spinning reserves, and black start capabilities. The continued stream of benefits derived from the CVP power facilities are of vital importance to the CVP water and power users. Loss of CVP hydropower generation results in a reduction in electric system reliability as well as potential increase in electrical costs.

Hydroelectric power, as produced by the CVP, has several advantages over most other sources of electrical power. These include high level of reliability, very low operating costs, and the ability to rapidly meet load changes. Another important benefit of CVP hydropower generation is that hydropower is a clean renewable energy source that does not produce atmospheric pollution. Hydropower is also the most efficient way to produce electrical energy with each kilowatt-hour being produced at an efficiency twice that of competing energy resources.

SHASTA AND KESWICK POWERPLANTS

The Shasta Powerplant is located on the western bank of the Sacramento River below Shasta Dam. The powerplant contains seven generating units, including two station service units. The powerplant, initially operated in 1944, has been expanded from the initial installed capability of 305,000 kW to an actual operating capability of 578,000 kW provided by five main generation units. The two station service units have a combined capability of 5,740 kW and can be used for Project Use and surplus power.

Keswick Dam was constructed downstream of the Shasta Powerplant to create an afterbay to regulate, or dampen the rapid flow fluctuations that occur when the Shasta Powerplant operations

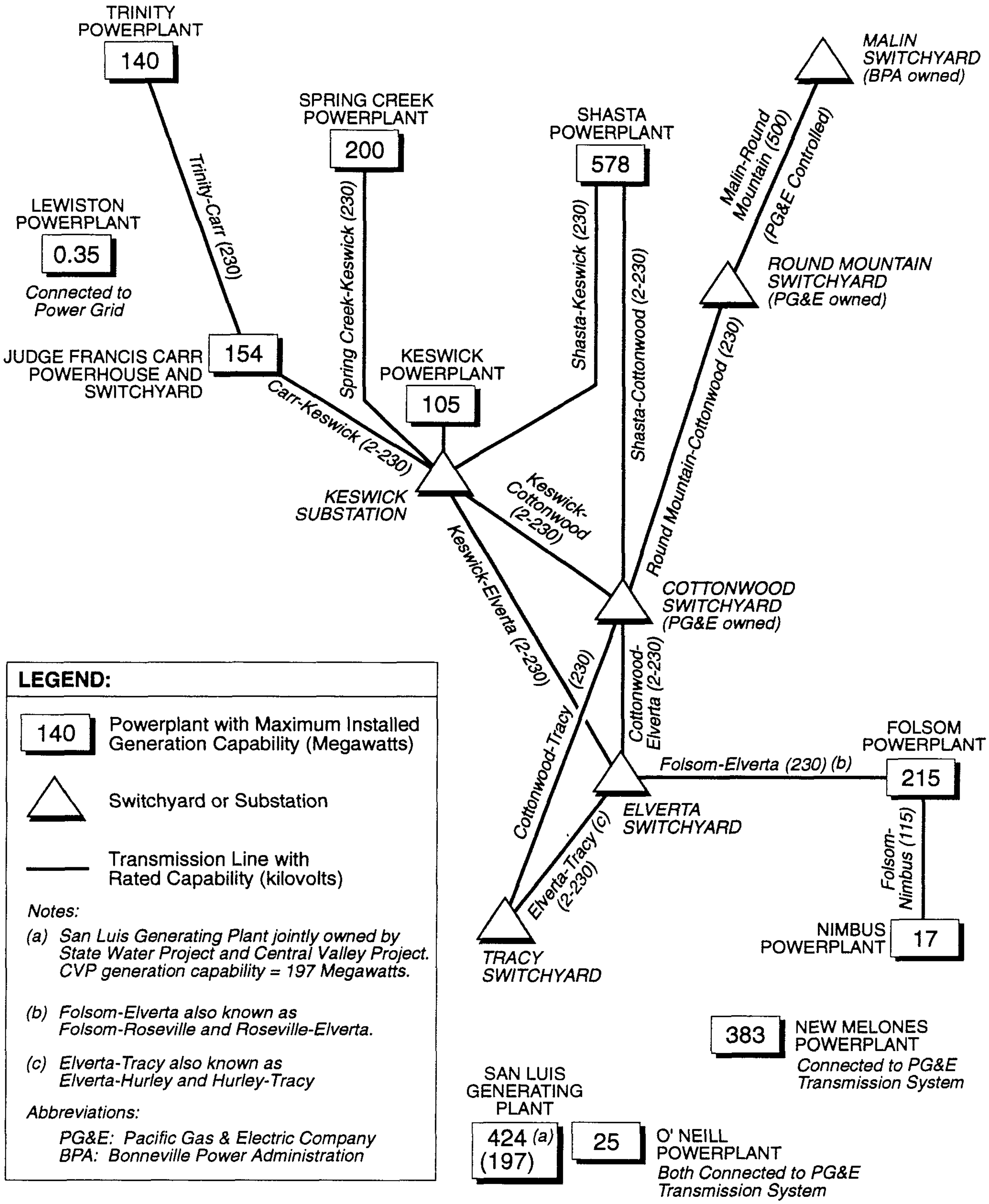


FIGURE II-1

CENTRAL VALLEY PROJECT POWER GENERATION FACILITIES AND ASSOCIATED WESTERN AREA POWER ADMINISTRATION MAJOR TRANSMISSION FACILITIES

change suddenly to meet changing power loads. Keswick Dam also includes a powerplant. The powerplant, initially operated in 1949, has a generation capability of 105,000 kW.

Switchyards, or substations, are located at both Shasta and Keswick powerplants. The substations increase the voltage to 230 kilovolts (kV) for transmission. Power also is provided to the City of Redding and the City of Shasta Lake.
The operations control room at the Keswick Powerplant also serves as the remote control center for Shasta Dam; Trinity Dam; Spring Creek Tunnel; Lewiston Dam; Whiskeytown Dam; Spring Creek Debris Dam; and powerplants at Shasta, Trinity, Lewiston, Judge Francis Carr (Clear Creek Tunnel), and Spring Creek (Spring Creek Tunnel).

TRINITY RIVER DIVISION POWERPLANTS

The Trinity River Division includes powerplants at Trinity Dam, Lewiston Dam, and downstream of the Clear Creek Tunnel and the Spring Creek Tunnel. Water from Trinity Dam flows through the Trinity Powerplant into Lewiston Reservoir. Water released from Lewiston Reservoir flows through the Lewiston Powerplant to the Trinity River or is diverted to the Clear Creek Tunnel. Water in the Clear Creek Tunnel passes through the Judge Francis Carr Powerplant before entering Whiskeytown Lake. Water released from Whiskeytown Lake flows to Clear Creek, the Clear Creek South Unit, or to Keswick Reservoir through the Spring Creek Power Conduit and Spring Creek Powerplant.

The Trinity and Lewiston powerplants, initially operated in 1964, have current maximum capabilities of 140,000 and 350 kW, respectively. The Trinity Powerplant has two units, and includes both high head and low head turbines to allow for adjustments with variable power pool elevations. The voltage is increased to 230 kV for transmission to the Judge Francis Carr Switchyard. Power generated at the Lewiston Powerplant is used for station service and the fish hatchery. Remaining power is delivered to the power grid.

The current maximum generation capability of the two units at Judge Francis Carr Powerplant, initially operated in 1963, is 154,400 kW. The actual operating capability is limited by operating conditions of the Clear Creek Tunnel (Reclamation, 1992). Mineral deposits in the tunnel reduce the capacity of the tunnel and the related generation capability. Tunnel operations are suspended periodically in the spring months to allow the mineral deposits to be removed naturally. Generation capabilities are restored as the tunnel is self-cleaned. The average generation capabilities range from 147,000 to 158,000 kW. The voltage is increased to 230 kV for transmission to the Keswick Substation.

The current maximum generation capability of the two units at Spring Creek Powerplant, initially operated in 1964, is 200,000 kW. The actual operating capability is determined by hydraulic capacity of the Spring Creek Tunnel. In a manner similar to the Clear Creek Tunnel, tunnel operations become limited due to mineral deposits and periodic cleaning operations. The voltage is increased to 230 kV for transmission to the Keswick Substation.

FOLSOM AND NIMBUS POWERPLANTS

The Folsom Powerplant is located on the north bank of the American River at the foot of Folsom Dam. The initial installed capability of the three generation units in 1955 was 162,000 kW. The installed generation capability was expanded to 215,100 kW; however, the reservoir operating levels in Folsom Reservoir limit the capability to 211,000 kW. The voltage generated at the Folsom and Nimbus Powerplants is increased to 230 kV for transmission.

Nimbus Dam was initially operated in 1955 as an afterbay for Folsom Powerplant. Nimbus Dam also includes a diversion structure to convey water to the Folsom South Canal. Water that flows through Nimbus Dam to the lower American River flows through the Nimbus Powerplant. The current maximum generation capability is 16,666 kW. The voltage generated at Nimbus is increased to 115 kV for transmission to Folsom.

SAN LUIS UNIT POWERPLANTS

The San Luis unit began operating in 1967 and includes both the San Luis and O'Neill reversible pump/generation facilities. O'Neill can either lift water from the Delta Mendota Canal to the O'Neill forebay or release water from the forebay to the canal. Water from the forebay can either be pumped into San Luis Reservoir or released to the San Luis Canal. Water from San Luis Reservoir is released to meet water user needs through the San Luis Generating Plant to the O'Neill forebay, where it is either released to the Delta Mendota Canal through O'Neill Powerplant or to the San Luis Canal.

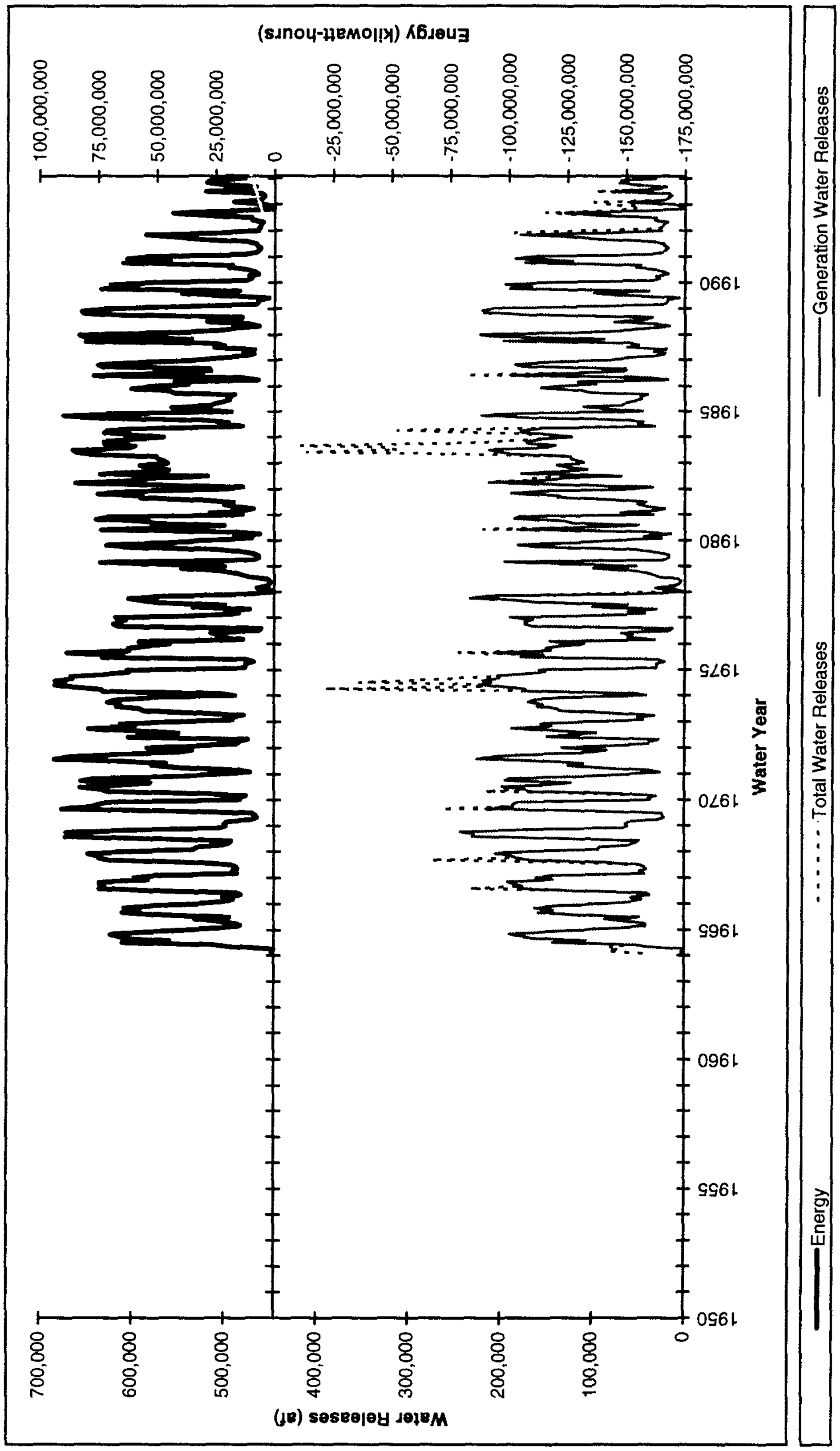
The installed generation capabilities of San Luis and O'Neill generating facilities are 424,000 and 25,200 kW, respectively. However, due to operating limitations, the generating capability of the San Luis Generating Plant is limited to 414,000 kW. The San Luis Generating Plant is shared with the California State Water Project. The CVP share of San Luis generation is 197,000 kW (based on the generating capability). Due to limitations on turbine operation, the total generation capacity at O'Neill Powerplant is 14,400 kW.

NEW MELONES POWERPLANT

The New Melones Powerplant was initially operated in 1979. The installed maximum generation capability of the two units is 383,340 kW. During the drought in the late 1980s and early 1990s, the operation was frequently limited. During portions of 1991 and 1992, the water level in New Melones Reservoir was lower than the minimum power pool level.

POWER GENERATION

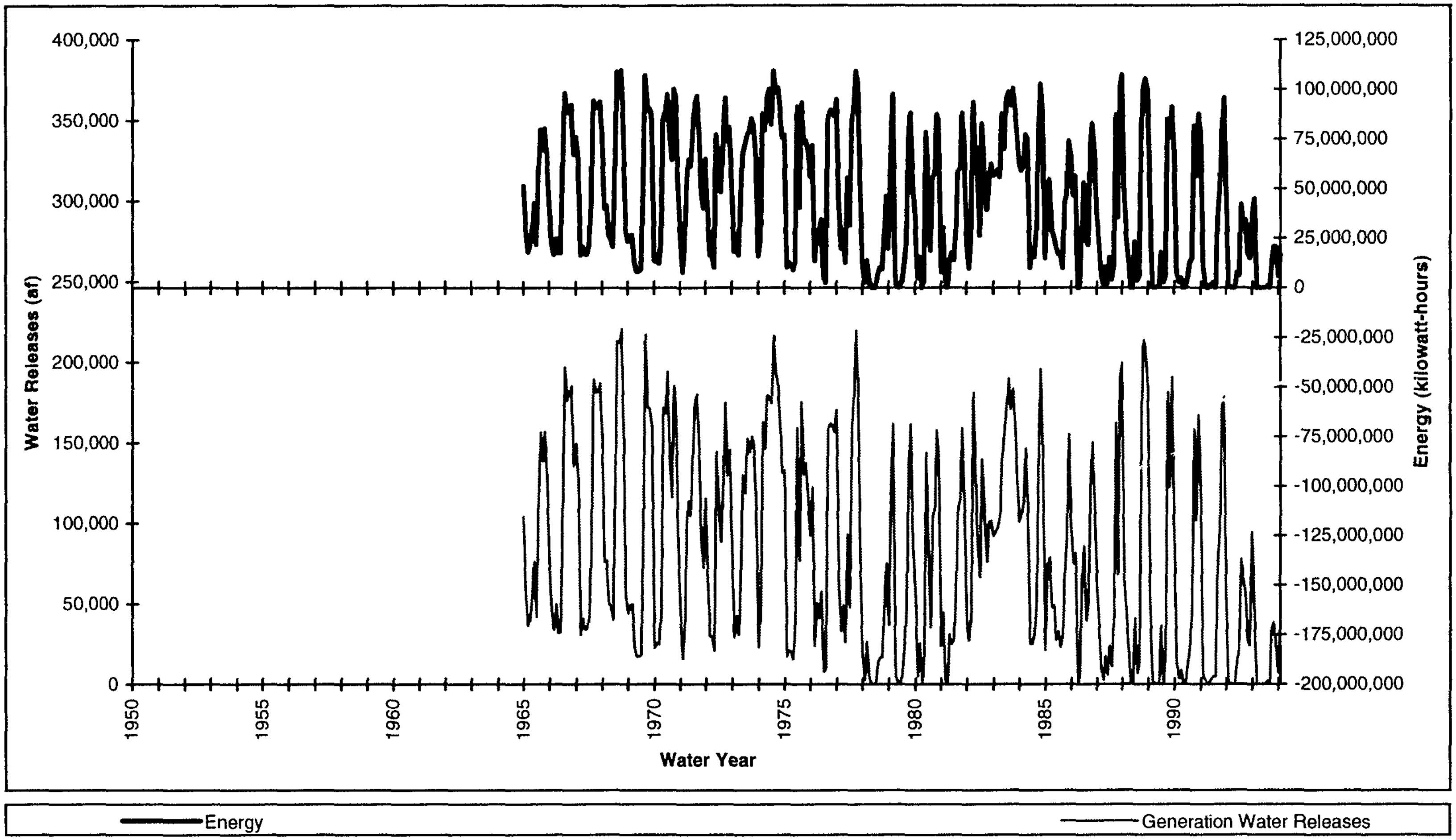
Historic power generation from CVP hydropower facilities fluctuates significantly with reservoir releases, as shown in Figures II-2 through II-11. Reservoir releases are significantly affected by droughts, minimum stream flow requirements, flow fluctuation restrictions, and water quality requirements. For example, recent dry periods reduced the water level in the New Melones Reservoir to below the minimum power pool levels and power could not be generated. Water releases and associated power generation are directly affected by changing climatic conditions, as



NOTES: (1) First year of power generation data available in 1964. First year of release data available in 1963.
(2) Generation for water years 1967 to 1993 includes Lewiston Powerplant.
(3) Operations data from Bureau of Reclamation.

FIGURE II-2

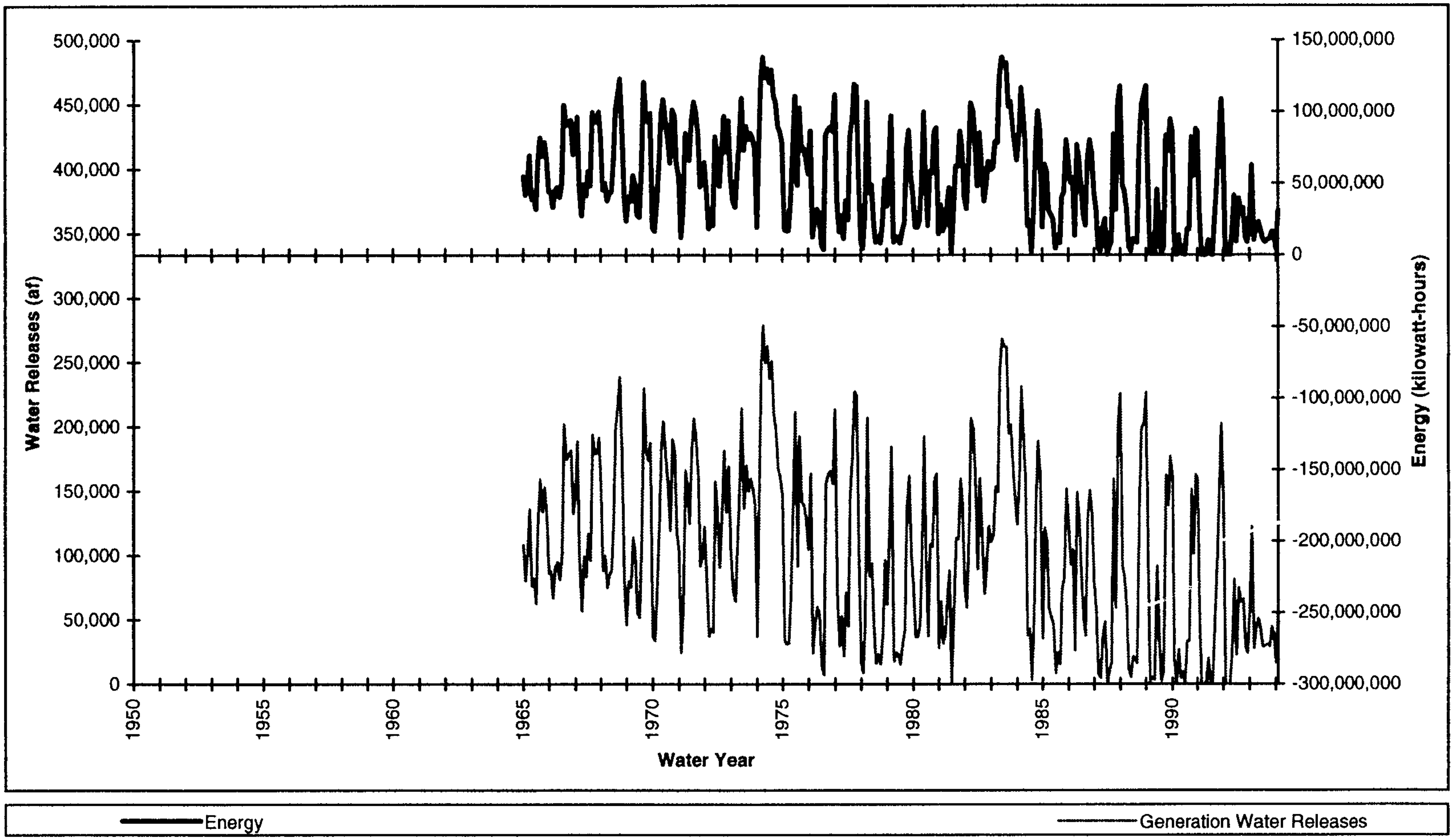
TRINITY DAM AND POWERPLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1963. First year of release data available in 1964.
(2) No total release data available for Judge Francis Carr Powerplant.
(3) Operations data from Bureau of Reclamation.

FIGURE II-3

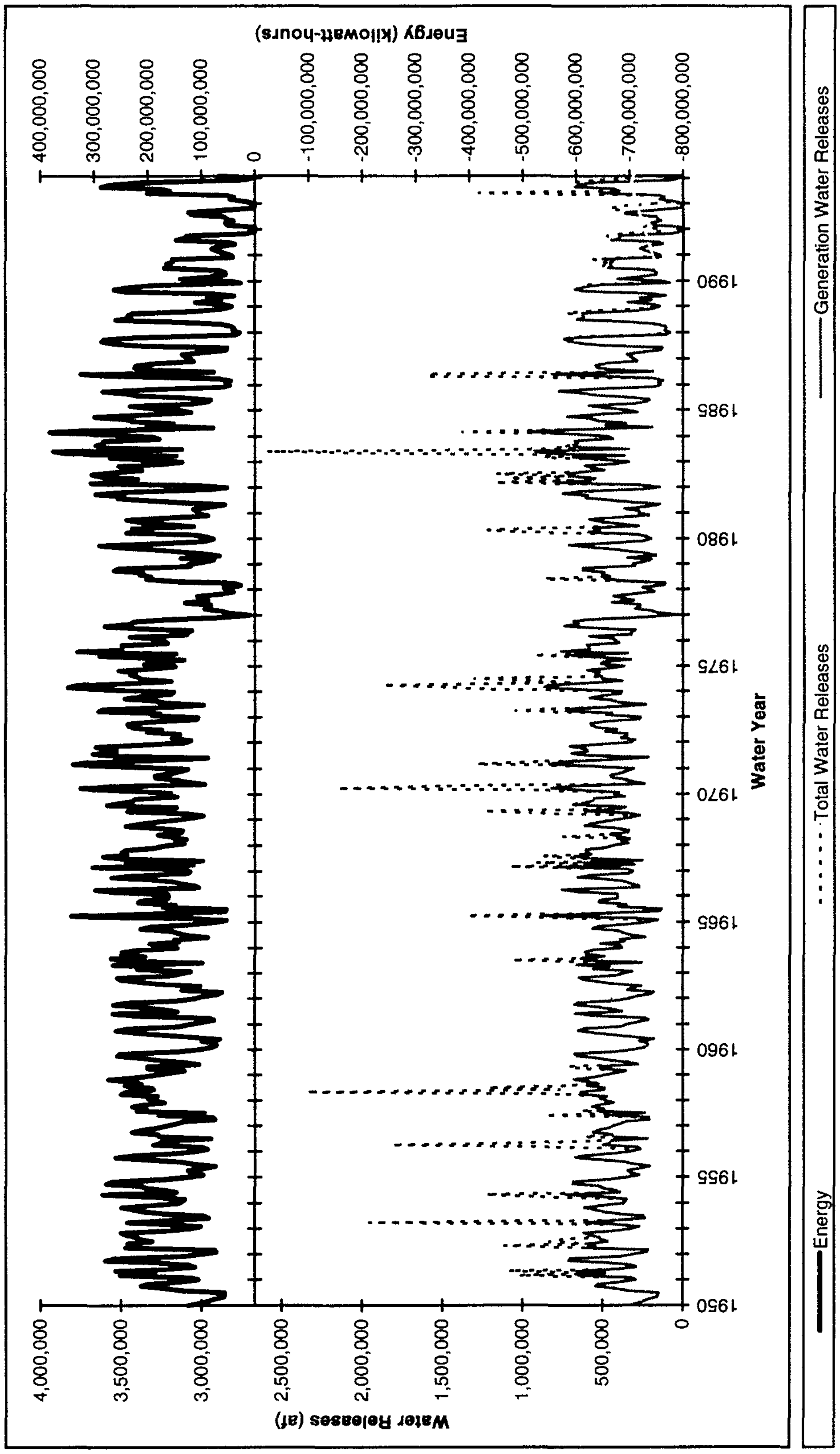
JUDGE FRANCIS CARR POWERPLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1964. First year of release data available in 1964.
(2) No total release data available for Spring Creek Powerplant.
(3) Operations data from Bureau of Reclamation.

FIGURE II-4

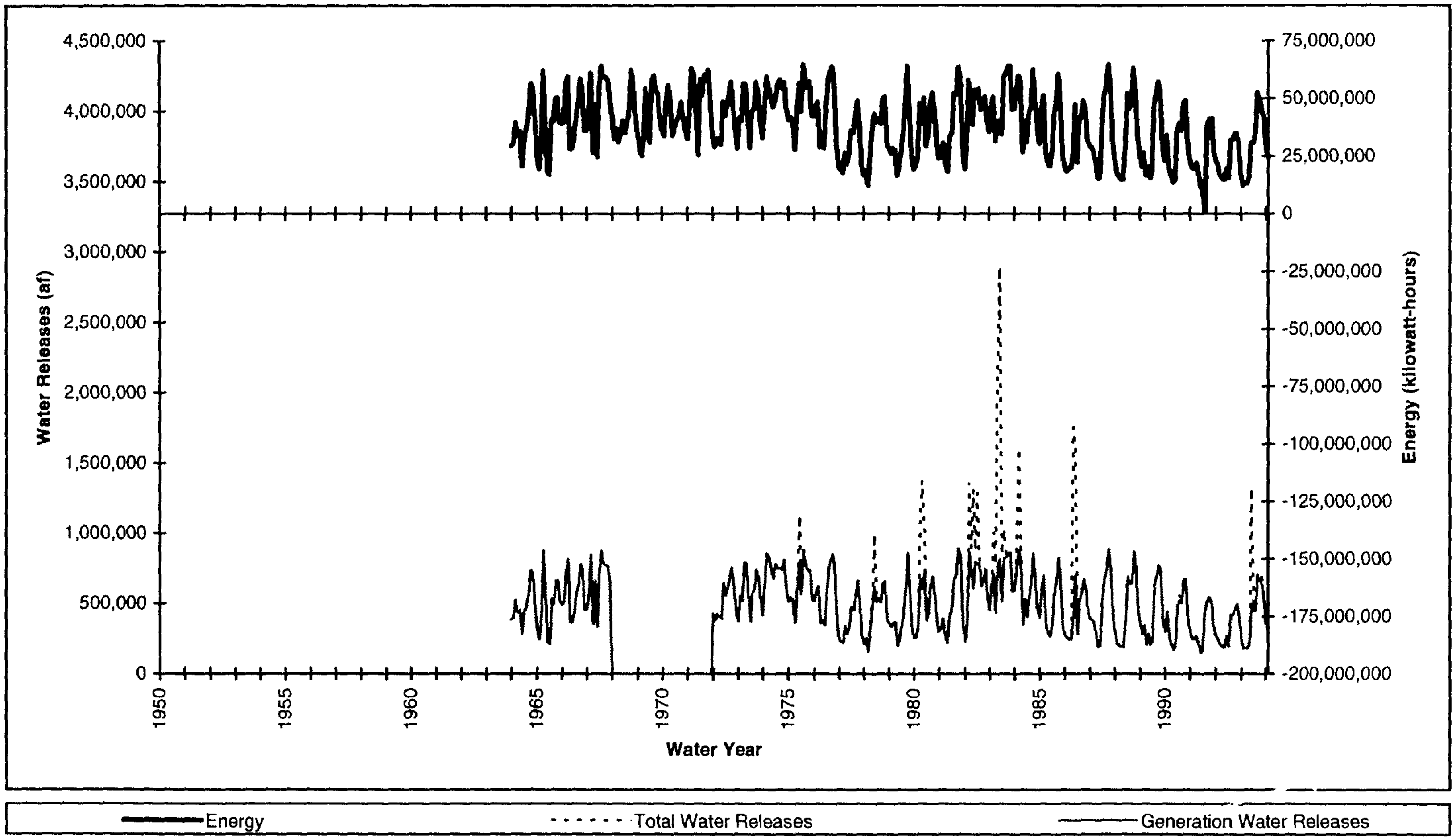
SPRING CREEK POWERPLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1949. First year of release data available in 1943.
(2) Operations data from Bureau of Reclamation.

FIGURE II-5

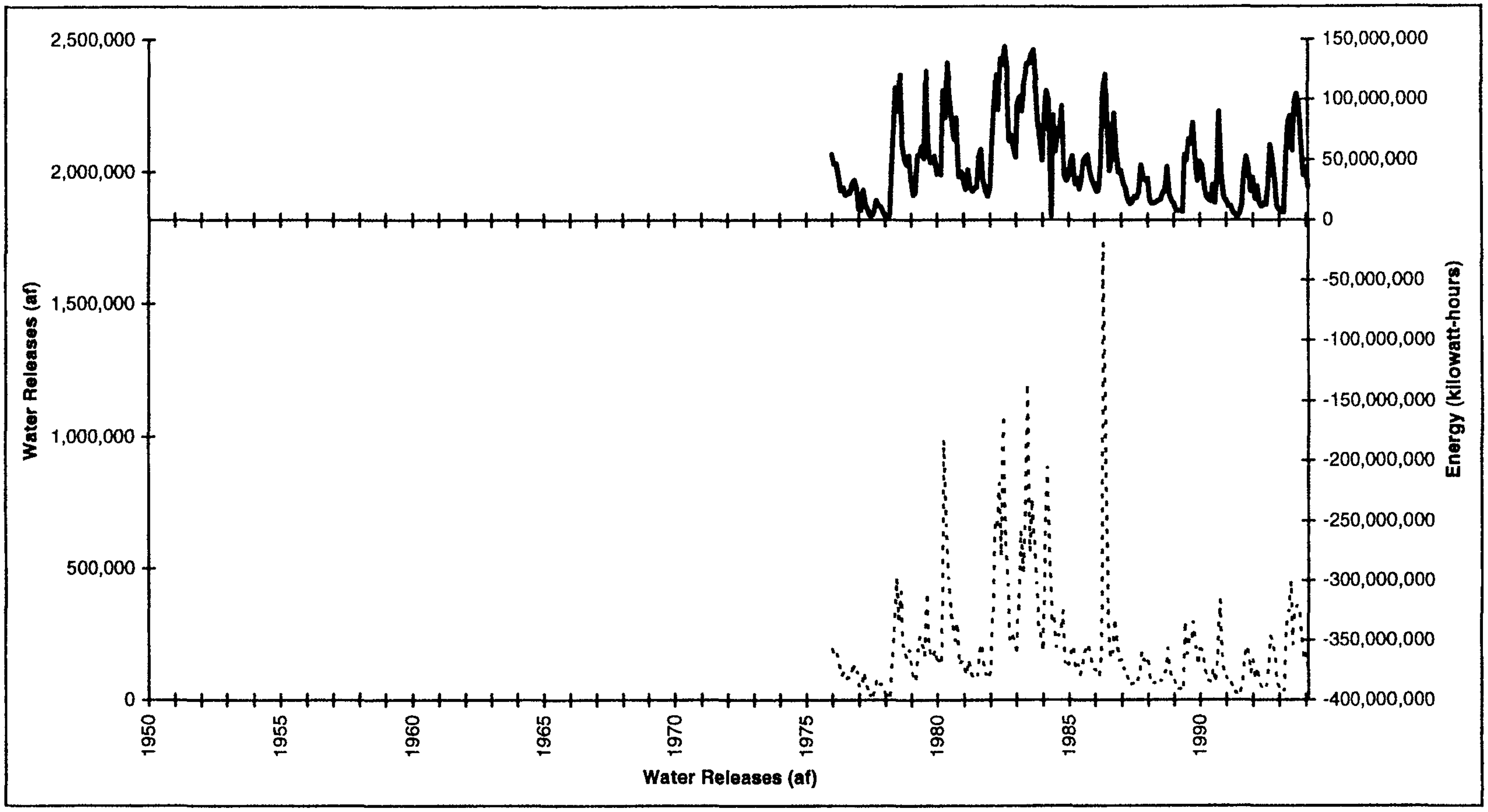
SHASTA DAM AND POWERPLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1949. First year of generation release data available in 1963. First year of total release data available in 1975. No generation releases were recorded for water years 1968 to 1971.
(2) Operations data from Bureau of Reclamation.

FIGURE II-6

KESWICK DAM AND POWERPLANT OPERATIONS

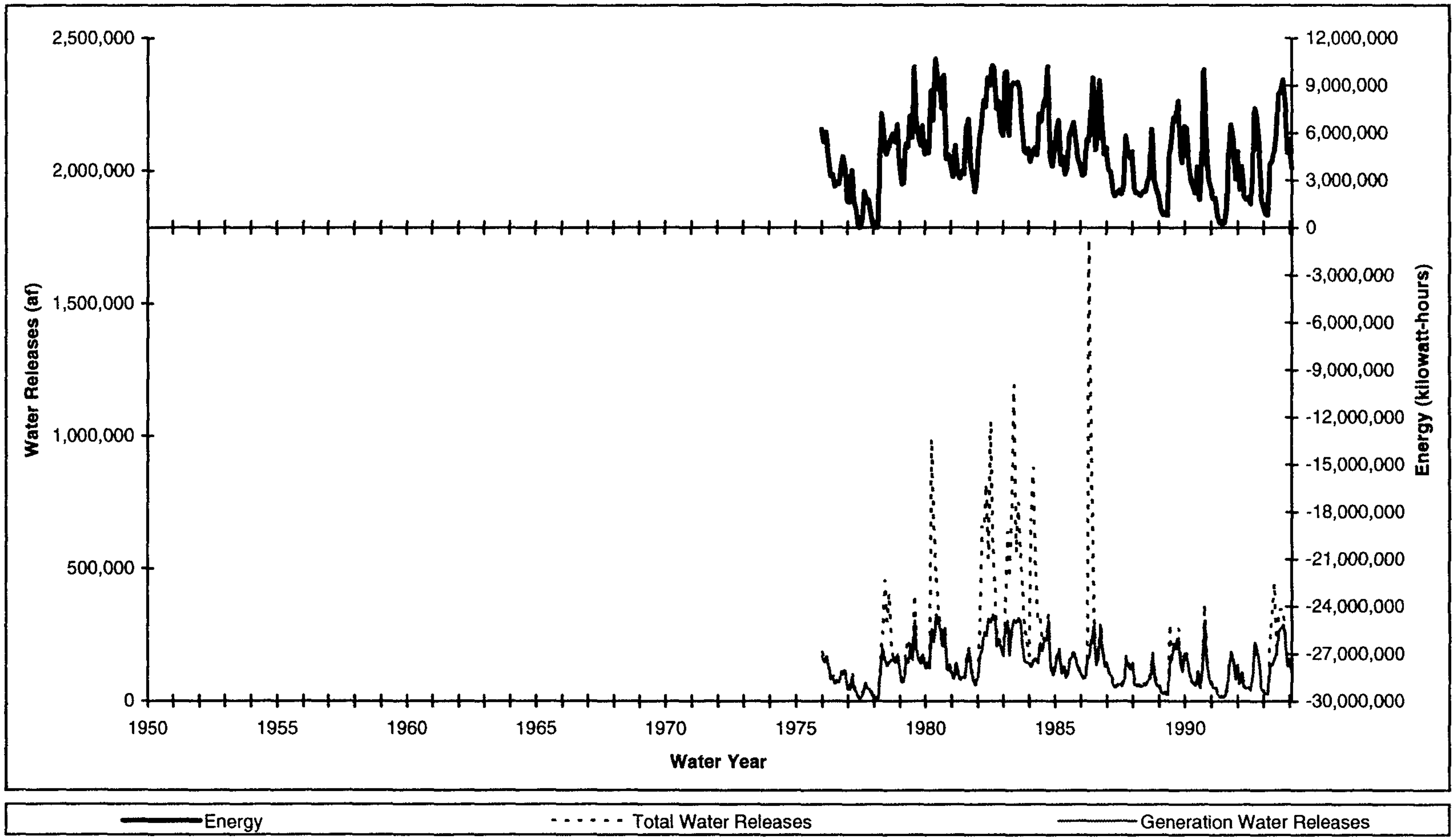


Energy ------ Total Water Releases

NOTES: (1) First year of power generation data available in 1955. First year of release data available in 1975.
(2) Power generation releases for Folsom not obtained.
(3) Operations data from Bureau of Reclamation.

FIGURE II-7

FOLSOM DAM AND POWERPLANT OPERATIONS



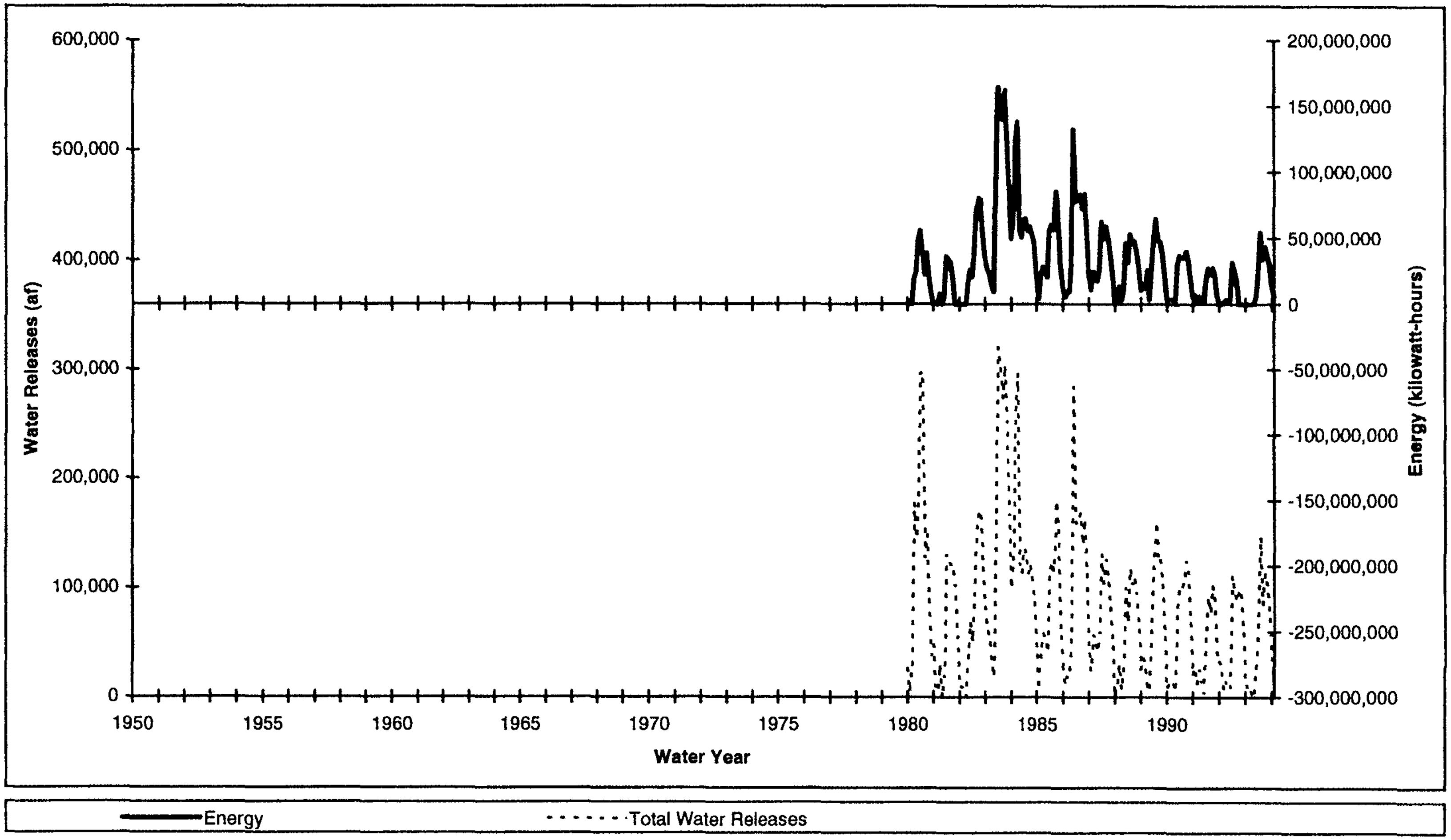
NOTES: (1) First year of power generation data available in 1955. First year of release data available in 1975.
(2) Operations data from Bureau of Reclamation.

FIGURE II-8

NIMBUS DAM AND POWERPLANT OPERATIONS

C —0 8 0 7 4 2

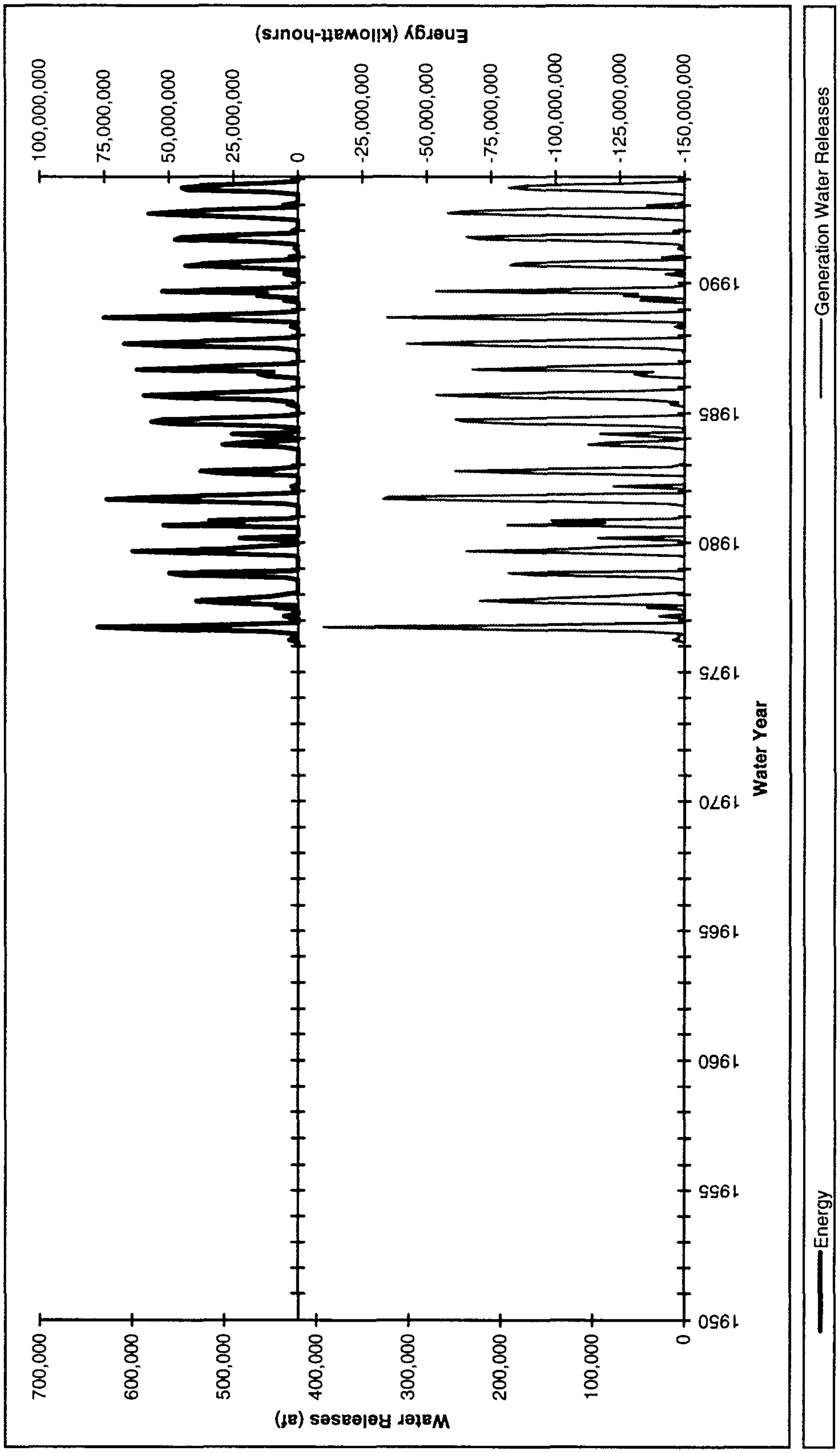
C-080744



NOTES: (1) First year of power generation data available in 1979. First year of release data available in 1979.
(2) Power generation water releases for New Melones not obtained.
(3) Operations data from Bureau of Reclamation.

FIGURE II-9

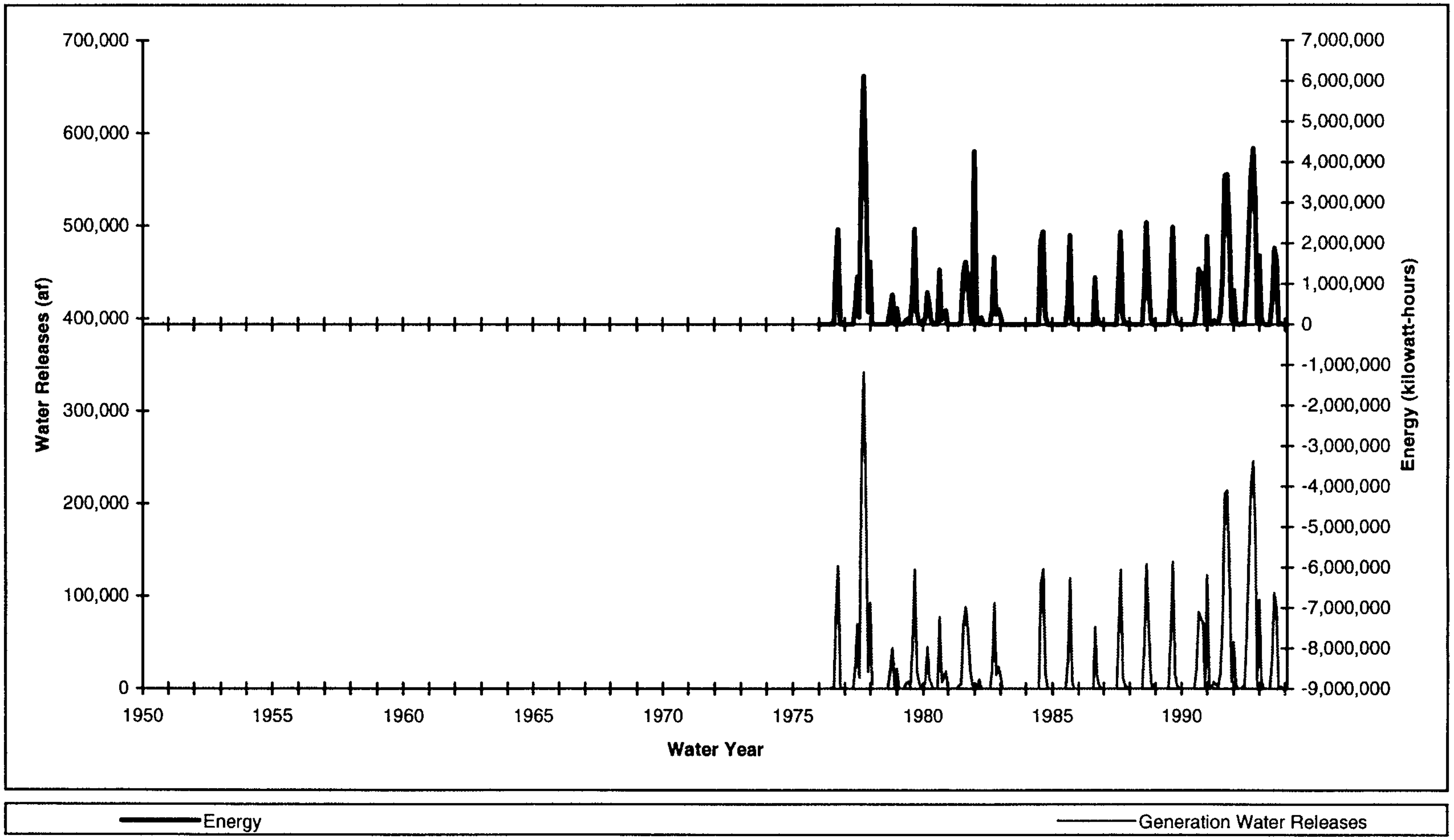
NEW MELONES DAM AND POWERPLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1968. First year of release data available in 1975.
(2) No total release data available for San Luis Generating Plant.
(3) Operations data from Bureau of Reclamation.

FIGURE II-10

SAN LUIS GENERATING PLANT OPERATIONS



NOTES: (1) First year of power generation data available in 1967. First year of release data available in 1975.
(2) No total release data available for O'Neill Powerplant.
(3) Operations data from Bureau of Reclamation.

FIGURE II-11

O'NEILL POWERPLANT OPERATIONS

shown in the figures. For example, power generation and releases increased significantly during periods of high precipitation in 1983 and 1986. The changes in climatic conditions appear to mask the effects of other operational changes, such as increased minimum flow requirements in the Trinity River initiated in 1982, which affected the power generation at Trinity, Lewiston, Carr, and Spring Creek powerplants. However, the impacts of bypassing the Shasta Powerplant, for downstream temperature control, are noticeable in the power generation values for Shasta Powerplant after the mid-1980s. Figure II-12 shows historic monthly total CVP power generation for the period 1984 through 1993.

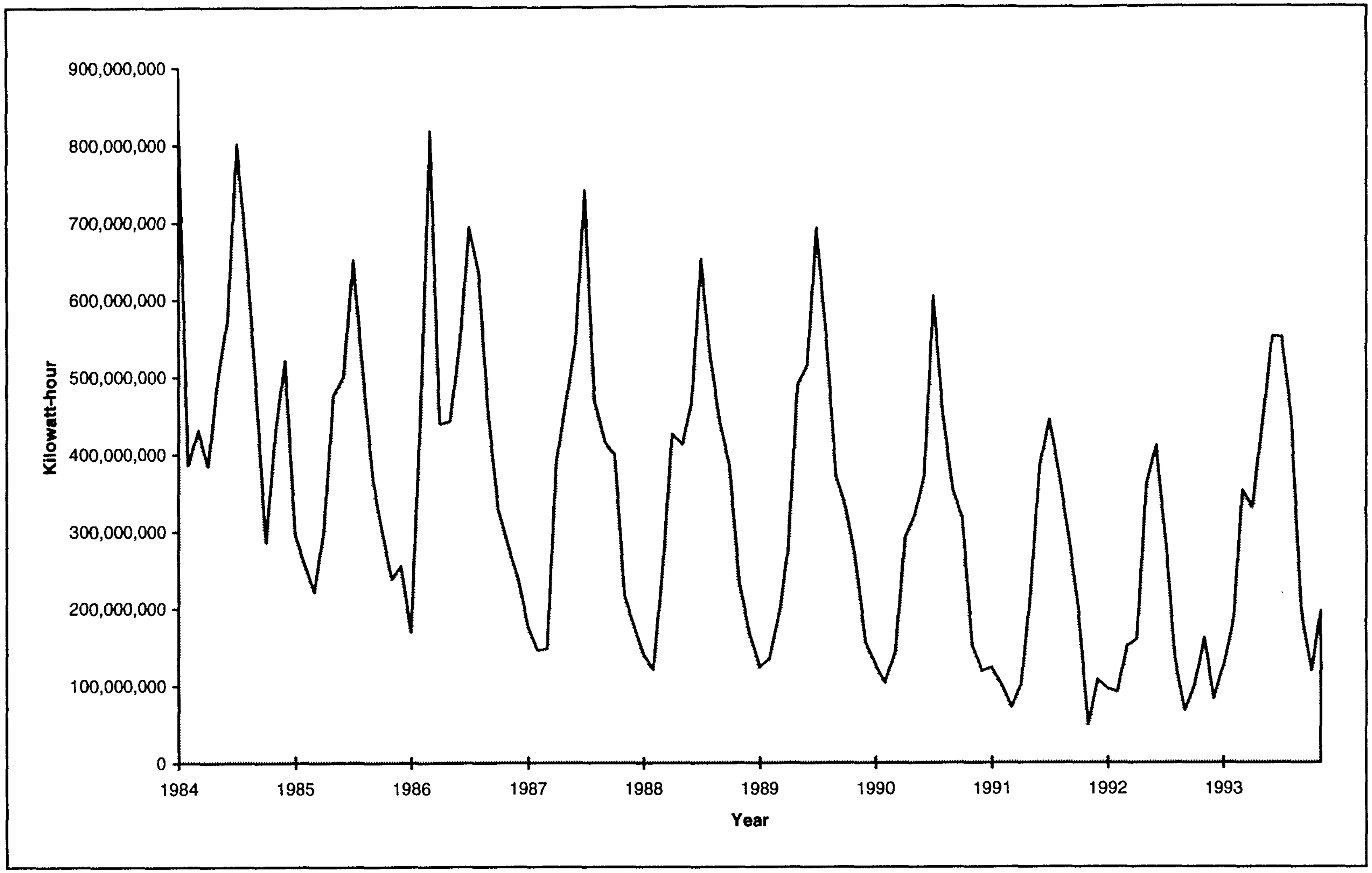
Recently, power generation has been affected by changes in minimum stream flow and water quality requirements. For example, Shasta Powerplant operations were affected by the State Water Resources Control Board (SWRCB) Water Rights Order 91-01 and the biological opinion issued by the National Marine Fisheries Service in 1992 to protect winter-run chinook salmon in the Sacramento River. The SWRCB Order and the biological opinion included maximum temperature requirements during specific months of the year. To meet the temperature requirements, cold water from the lower levels of Shasta Lake was released during the critical periods. Outlets in the dam that allow release of colder water are not connected to the Shasta Powerplant. Therefore, to meet temperature requirements, the Shasta Powerplant was bypassed and annual power generation was significantly reduced. The construction of a temperature control device for Shasta Dam will allow the colder water to pass through the powerplant.

Operations under water quality requirements have also affected the monthly release patterns and resulting power generation at all CVP hydro facilities. Historically, maximum releases from CVP facilities occurred during the summer months during periods of high irrigation water demand, which corresponded to the period peak power loads occurred within the area served by CVP generation. However, recent water quality requirements have increased the need for water releases in the winter and spring months causing less water to be available for release during the peak summer months. Therefore, power generation has been shifted from the summer period to other months and the peak generation during the summer period has been reduced. Peak generation may not occur at the same time as peak power loads. Changes in power generation patterns affect coordinated operations of both PG&E and CVP facilities.

CENTRAL VALLEY PROJECT POWER CUSTOMERS

The CVP power generation facilities were initially developed based on the premise that power could be generated to meet Project Use loads. Currently, Project Use demand uses on average approximately 25-30 percent of the power generated by the CVP. Historic on- and off-peak Project Use summed for the major CVP pumping plants, which account for about 90 percent of total Project Use demand, is shown in Figure II-13.

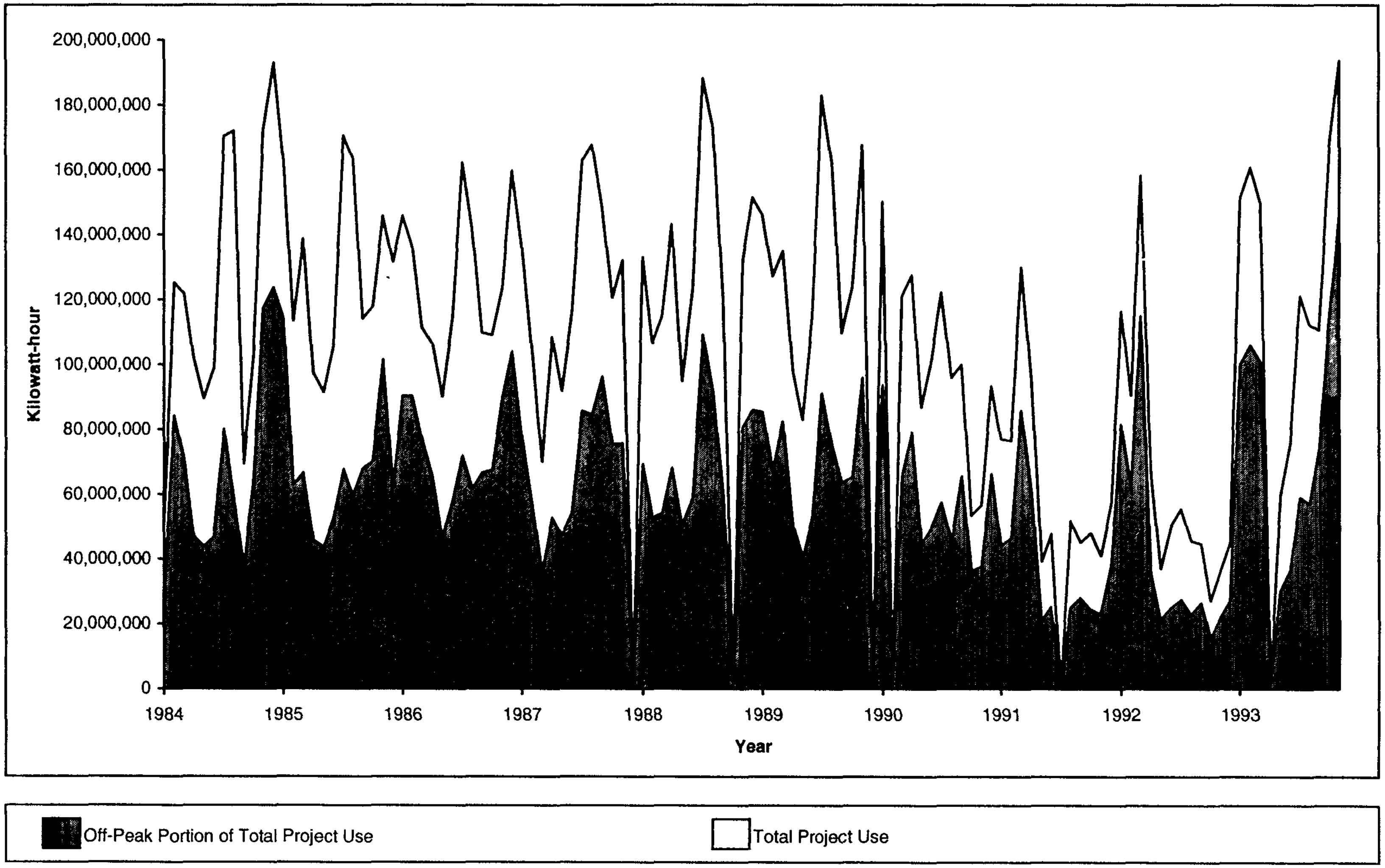
The Reclamation Act of 1939 provided for surplus power, power not needed for Project Use loads, to be sold first to Preference Customers. Specifically, the Act stated "... in said sales of leases, preference shall be given to municipalities and other public corporations and agencies and also to cooperatives and other non-profit organizations financed in whole or in part by loans made pursuant to the Rural Electrification Act of 1936 and any amendments thereof." By Reclamation law, the Preference Power Customers include irrigation and reclamation district,



NOTE: Includes Trinity, Shasta, American, Eastside, and West San Joaquin Divisions.

FIGURE II-12

HISTORIC MONTHLY CVP GENERATION



NOTE: Includes San Luis Unit, Delta Division, and CVP Portion of Banks Pumping Plant only.

FIGURE II-13

HISTORIC MONTHLY CVP PROJECT USE

cooperatives, public utility districts, municipalities, California educational and penal institutions, and federal defense and other institutions.

CVP power is used throughout Central and Northern California, first to meet the authorized needs of the project including irrigation pumping, M&I pumping, fish and wildlife, and station service. As mentioned earlier, 25-30 percent of the CVP total power generation is used to support Project Use demand. The remaining power is marketed by the Western Area Power Administration to Preference Customers such as federal agencies, military bases, municipalities, public utilities districts, irrigation and water districts, and state agencies. Power produced in excess of Project Use load and Preference Customer deliveries is delivered to PG&E under an agreement which allows for the sale, interchange, and transmission of electrical power and energy between the federal government and PG&E. The current Preference Power Customers include 11 municipalities, 1 rural electric cooperative, 23 federal installations, 8 state-owned installations, 10 public utility districts, 22 local water and irrigation districts, and the Bay Area Rapid Transit District.

POWER MARKETING

Surplus commercial firm power may be sold to non-preference utilities. The first commercial power generated by the CVP was generated by the Shasta Powerplant and was sold to PG&E in 1945. The initial Preference Power Customers began to take delivery in the late 1940s.

Hydropower generation does not always occur during times of peak power loads of the CVP and Preference Power Customers. The 1930s plan for the CVP included construction of fossil-fuel thermal powerplants to be located near Tracy to provide baseload power generation. The hydropower generation plants were to be operated to meet CVP Project Use peak power loads. The initial concept also included an extensive transmission grid to provide Project Use power to all CVP facilities and to provide commercial firm power to Preference Power Customers, and transmit power from all CVP hydropower plants. This project was reevaluated in the late 1940s as the CVP facilities were constructed. In 1951, it was determined that it would be more cost-effective to co-utilize generation and transmission facilities constructed by PG&E wherever possible to avoid duplication of facilities.

In 1967, Reclamation and PG&E signed an agreement (Contract No. 14-06-200-2948A, or "Contract 2948A") which allowed for the sale, interchange, and transmission of electrical power between the federal government and PG&E.

Under the terms of Contract 2948A, the generation of CVP hydropower plants is delivered to PG&E, along with Western power purchases. In return, PG&E supports firm power deliveries to CVP Project Use needs and Preference Power Customers. To the extent that Reclamation's CVP hydropower generation plus Western firm power purchases exceed Project Use and contractual obligations to CVP Preference Power Customers, the excess energy may be either sold into an energy bank account with PG&E (commonly referred to as EA2) for repurchase at a future time, or sold as surplus energy. Conversely, if the CVP hydropower generation plus Western power purchases are less than the combined Project Use and Preference Customer loads, energy may be withdrawn from the EA2 bank account, or if necessary, Western may purchase additional power from PG&E.

Contract 2948A also included limits on contracts for Preference Power Customer loads to a stated maximum simultaneous peak load of 1,152,000 kW. The actual maximum contractual obligation of the power customers was calculated based upon different types of loads, timing of loads, and agreements for withdrawing power when CVP generation and Western power purchases cannot meet loads. The power accounting procedures under 2948A are based upon the assumption that all power is transmitted from the CVP generating units to the Tracy Switchyard. The power is then dispatched to the CVP Preference Power Customers and CVP Project Use loads. Therefore, all loads and available capacity are adjusted for line losses to the "load center" at the Tracy Switchyard.

In 1992, Western and PG&E resolved outstanding disputes concerning Contract 2948A. The Settlement Agreement addressed capacity purchases, purchase rates, project dependable power calculations, capacity credits from generation facilities in the Pacific Northwest, exchange accounts, sale and transmission of excess capacity, and several other provisions (Western, 1992b).

POWER GENERATION AND POWER PURCHASES

As discussed above, the CVP power is not necessarily generated at the appropriate times to meet peak power needs of the CVP Project Use and the Preference Power Customers. In addition, power generation is frequently reduced due to droughts and changes in minimum stream flow requirements. Therefore, to maximize the beneficial use of CVP power, Western frequently exchanges, or banks, power with PG&E and purchases power from PG&E and other entities, such as suppliers in the Pacific Northwest, to meet Project Use loads and/or Preference Power Customer loads.

The CVP is operated whenever possible to optimize the use of generated power. Reclamation, Western, and PG&E work together on a daily basis comparing hydropower availability, total loads including PG&E loads, and availability of PG&E resources and transmission capabilities. Daily operations are pre-scheduled the previous day. The Reclamation dispatch center determines the required hourly stream flows and releases from Keswick, Lewiston, Tulloch, and Nimbus reservoirs to meet water demands, water quality requirements, and generation needs. Reclamation sends the information to the Western dispatch office which coordinates with the PG&E dispatch center. All three entities confirm and, if necessary, adjust the schedule.

POWER SALES

Power rates for Preference Power Customers are determined by Western. Western completes an annual Power Repayment Study (Western, 1993) to determine if revenues from power sales will be sufficient to pay all costs assigned to the CVP power purposes, including operation and maintenance and interest expenses. The revenues must be sufficient to recover the power investment of the CVP facilities within a 50-year period after the facilities become operational or as provided by federal law. The revenues also must be sufficient to recover the investment in federal transmission facilities and the cost of replacement of all power facilities within the service life of the facilities up to a maximum period of 50 years.

CHAPTER III

ENVIRONMENTAL CONSEQUENCES

Chapter III

ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter provides a summary of potential changes to CVP power generation, Project Use, and the market value of CVP power that would result from the implementation of the alternatives considered in the PEIS. The PEIS alternatives include a range of component CVPIA actions that would affect CVP facility and river operations, and resulting CVP power generation and Project Use. These actions include reoperation and (b)(2) Water Management toward meeting target flows on CVP-controlled streams, firm Level 2 refuge water supplies, and increased instream Trinity River flow requirements. Additional actions include the retirement of land pursuant to the San Joaquin Valley Drainage Plan, and the acquisition of water from willing sellers for delivery to wildlife refuges, increased instream flows, and increased Delta outflow.

The chapter begins with a brief discussion of the impact assessment methodology used for analysis of the PEIS alternatives, followed by a description of the assumptions and operational criteria used in the No-Action Alternative which serves as the base condition for the PEIS impact analysis. For each alternative, the objectives and CVPIA actions included in the alternative are presented along with model simulation results showing the re-operation of CVP power facilities. This chapter does not deal with Power Restoration Fund costs or with non-CVP power resources.

IMPACT ASSESSMENT METHODOLOGY

Currently, CVP power is marketed under Contract 2948A, as described in the Affected Environment. This contract provides for the integrated operation of the CVP generation with the PG&E system. The contract expires the end of 2004 and is not expected to be renewed. While the CVP has historically been operated, to the extent possible, to meet the requirements of this contract and to receive the benefits thereof, it is not expected to continue to be operated in a similar manner after contract termination in 2004. For the purposes of this study, it has been assumed that the CVP will be operated to meet authorized project purposes which include providing water deliveries to water users, meeting fish and wildlife purposes, and power generation. Within given operating constraints, the CVP will be operated to maximize meeting load requirements of the CVP Project Use and Preference Customers.

The impacts associated with each alternative were viewed from the perspective of the change in available CVP power production, rather than attempting to estimate the total cost of the power supply requirements for CVP power customers under each of the various alternatives. The difference in power generation as well as the difference in monthly on- and off-peak Project Use capacity and energy, between the alternatives and the No-Action Alternative, was evaluated in order to estimate the impacts associated with each alternative.

CVP OPERATIONS

The Project Simulation Model (PROSIM) and San Joaquin Area Simulation Model (SANJASM) were used to simulate monthly CVP water facility operations, as discussed in the Water Supply and Facilities Operations Technical Appendix. The model simulations were carried out for the period 1922 through 1990, using historical hydrology adjusted for a projected 2022 level of development. The power module of the PROSIM model was used to calculate monthly CVP generation, available capacity, and CVP Project Use energy and capacity. On- and off-peak periods used to compute Project Use energy and capacity were based on the current Contract 2948A criteria. See PROSIM M/M TA for a discussion of the power module.

The simulation of CVP water facilities was conducted on a monthly time step using generalized reservoir operating rules and system criteria. The model simulation results are appropriate for the programmatic level of comparative analysis required for the PEIS. The power information computed for each of the alternatives should only be interpreted in a comparative manner, and is only intended to provide an indication of the potential changes to CVP power generation, available capacity, and Project Use that would result from the implementation of the alternatives considered in the PEIS.

MARKET VALUE OF POWER

The PROSYM electric production cost model used the output from the PROSIM model and power module to develop an estimate of the annual change in the market value of CVP power production for each alternative, as compared to the No-Action Alternative. PROSYM is a proprietary model that simulates the economic dispatch of an electric system to optimize the use of the generation resources in meeting a given load curve. A description of the PROSYM model is provided in the PEIS Impacts Study conducted by Western (Western, 1997).

The CVP energy generation and associated generating capacity availability under average and adverse dry hydrologic conditions were developed for use with PROSYM. Generation in an average year was based on a monthly average of the generation at each powerplant over the 69 years of simulation from the PROSIM model.

To determine the dry year energy and capacity which are structured to provide a high level of system reliability, a level of hydroelectric production was chosen such that the CVP capacity would be available at least 90 percent of the time for any given month (barring equipment failure). Thus, a 90 percent hydrologic exceedance level was utilized (i.e., the level of energy assumed to be produced in any month will be exceeded 90 percent of the time). The resulting 12 months of energy levels developed for the PEIS alternative analysis comprise a set of synthetic years that do not resemble any specific operating or chronological year within the 69-year simulation period. Similarity to a specific hydrologic year was not assumed to be important when the market value of the CVP capacity (i.e., level of capacity supported with energy) is being determined, since each month is evaluated independently of other months and the market will value the capacity available, and hence the potential to offset additional capital expenditures in any month based on the applicable reliability criteria (i.e., 90 percent exceedence).

The use of this synthetic adverse dry year is consistent with assumptions used in the Western's Sierra Nevada Region's (SNR) 2004 Marketing EIS. It should be noted that use of this methodology implies a certain level of risk for CVP Preference Power Customers. This synthetic year does not necessarily represent a worst case generation year or worst case of net available power for marketing, but is for use in comparison of alternatives to the No-Action Alternative.

To create this synthetic year, the energy generated in each month (over the 69-year simulation) was sorted into ascending order. A month and year were then selected such that the generation in that month would be exceeded 90 percent of the time. This was done by month such that the generation in the dry year January would be exceeded in 90 percent of the Januarys, the generation in the dry year February would be exceeded in 90 percent of the Februarys, and continued throughout the year. The capacity available from each powerplant and the required Project Use were defined to be the capacity and Project Use as reported by the PROSIM power module for each of the 90 percent exceedence months.

The monthly available capacity and energy were dispatched by the model to determine hourly generation data. Hourly data are used to properly value energy by the time of day it is produced. Specifically, energy generated during on-peak (high load) periods has a higher value than energy produced in off-peak (low load) periods. Hourly data are also used to determine the actual load-carrying capacity of the hydropower system. The monthly capacity, as reported by the PROSIM model, is a "head dependent" capacity based on the average amount of storage in each reservoir for a month. In the determination of the load-carrying capability of the system the "head-dependent" capacity acts as a maximum, but the amount of energy generated at each powerplant is also taken into account, as well as the shape of the load curve into which the hydropower is dispatched and certain flow constraints and downstream regulation requirements. The load-carrying capability is the maximum level of sustainable energy production within a given load shape that results in minimizing the acquisition of additional capacity. Load-carrying capability may also be referred to as "capacity supported with energy."

To develop the hourly generation data, load curves were developed for the Project Use load and the customer load. The customer load used in the analysis was the total 1994 Northern California Preference Customer load, as supplied by SNR. The hourly Project Use load curve was developed by reshaping the historic 1995 Project Use load curve to meet the monthly on- and off-peak Project Use load estimates from the PROSIM model.

The monthly available capacity and generation at each CVP powerplant was dispatched into a combination of the hourly customer load and Project Use load using the PROSYM production cost model in order to create an hourly dispatch.

In addition to changes resulting from the termination of Contract 2948A, the restructuring of the electric utility industry currently underway is expected to also play a significant role in how the CVP electrical facilities are operated in the future. Industry restructuring will allow entities, including CVP preference customers, who are now only able to access power supply from PG&E and SNR to access other energy suppliers and obtain the necessary transmission service. This universal market access will allow many, if not all, of SNR customers to participate in power markets that currently are only available to utility customers. The analysis presented in the PEIS is based on modeling assumptions that all SNR customers have equal market access.

The value of monthly capacity available for sale was determined based on the monthly maximum level of load-carrying capability (capacity supported with energy) available under adverse hydrologic conditions. In addition, the monthly capacity available without energy was also considered based on its potential value for providing reserves or other ancillary services.

Since the analysis of the PEIS assumes a 2022 level of development, one may expect that condition will be representative of a general long-term balance in electrical resources and loads and that any changes in the operation of the CVP generation will be reflected in the operation of the marginal system resource. While conditions used in the analysis are generally reflective of future conditions, the price levels used in this analysis are assumed to be expressed at 1992 levels in order to be consistent with other economic analyses conducted in the PEIS. Due to the uncertainty involved, the level of technology involved in future generation resources, as well as their efficiencies, were assumed to remain at current levels.

CVP power generation is predominantly peaking in nature, and the system is energy constrained during adverse water conditions. For this reason and since long-term load resource balance was assumed, capacity from the CVP was valued based on the assumption that any change in the CVP power capacity would be offset by a corresponding change in the level of construction of simple-cycle combustion turbines. As a result of the industry restructuring, it was assumed that future capacity additions would be made by private generation companies and that very little public financing would be involved in future capacity additions. The assumptions used in this analysis are summarized below:

- Private Financing based on 30 percent equity position.

- Capital Replacement Cost of about $340 to $410/kilowatt for simple-cycle combustion turbines, including air quality protection facilities (1992 dollars).

- Debt Service of $45 to $54/kilowatt/hour with financing of 25 years at 10.45 percent.

- Annual Operation and Maintenance Costs, Taxes, and Transmission Costs at $26/kilowatt-year.

Based on these assumptions, the value of capacity was estimated to be $6.28 per kilowatt-month.

Capacity without energy (available capacity less capacity supported with energy) was also valued based on its ability to provide certain ancillary services (primarily spinning and installed reserves). This capacity was valued at 20 percent of the value used for the capacity supported with energy. The value of energy produced by the CVP was estimated based on a marginal heat rate approach. To the extent the CVP power output is increased or decreased in a particular time period, an opposite change will occur in the output of the marginal unit which is operating at that same time. The marginal heat rates for Northern California, Pacific Northwest, Southwest, and Southern California from which power may be transmitted were reviewed. Monthly time-of-day marginal production costs for these areas were derived based on regional gas prices and adjusted to reflect transmission losses to Northern California and a 5 percent transaction adder to the producer. It was then assumed that, given industry restructuring, it would be possible to access the source of energy having the lowest delivered cost. This resulted in the alternative energy source varying monthly and by time of day (on-peak versus off-peak). The monthly on- and off-peak values (1992 dollars) for energy used in this analysis are summarized in Table III-1.

TABLE III-1

ESTIMATED DELIVERED PRICE FOR MARGINAL ENERGY

Month	On-Peak Delivered Price ($/MW-hour)	Off-Peak Delivered Price ($/MW-hour)
January	$19.82	$16.55
February	$18.90	$16.30
March	$16.42	$14.54
April	$14.93	$13.41
May	$13.42	$11.67
June	$14.31	$12.92
July	$16.63	$14.40
August	$17.90	$16.85
September	$18.58	$17.10
October	$19.25	$17.32
November	$20.90	$18.69
December	$22.54	$18.99
Annual Average	**$17.80**	**$15.73**

NOTE:
Price includes energy value only, does not include capacity component.

NO-ACTION ALTERNATIVE

Under the No-Action Alternative, the CVP power generation facilities are operated in a manner similar to the operations discussed under Affected Environment. CVP system operations are consistent with the criteria defined in the Long-Term Central Valley Project Operations Criteria and Plan (October 1992). The primary differences between operations under the No-Action Alternative and the Affected Environment discussion are primarily related to changes due to the Bay-Delta Plan Accord and revised Stanislaus River operations. The details of the assumptions and criteria used in the simulation of CVP facilities in the No-Action Alternative is discussed in the Surface Water Supplies and Facilities Operations Technical Appendix.

The average annual generation at each CVP powerplant is shown in Figure III-1. The average annual CVP generation for the No-Action Alternative for long term average (1922-1990) and dry (1929-1934) hydrologic conditions is 4,935 gigawatt-hours (GWh) and 2,764 GWh, respectively. Monthly generation values are presented in Figure III-2 and Table III-2 for all alternatives. The simulated average monthly total CVP available capacity is presented in Figure III-3 and Table III-3, for the average and dry periods. The average monthly available capacity for the long term

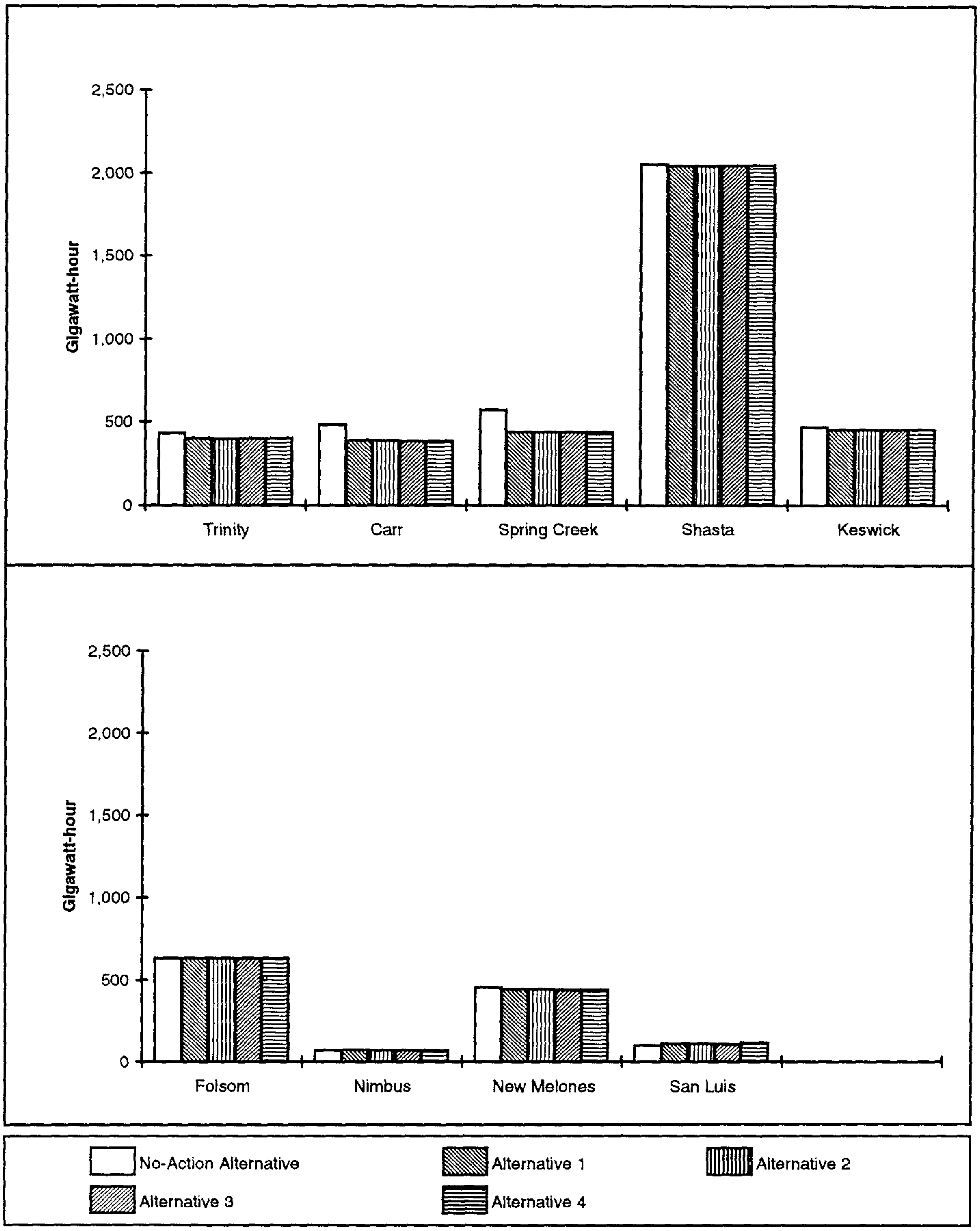


FIGURE III-1

SIMULATED AVERAGE ANNUAL GENERATION AT CVP POWERPLANTS

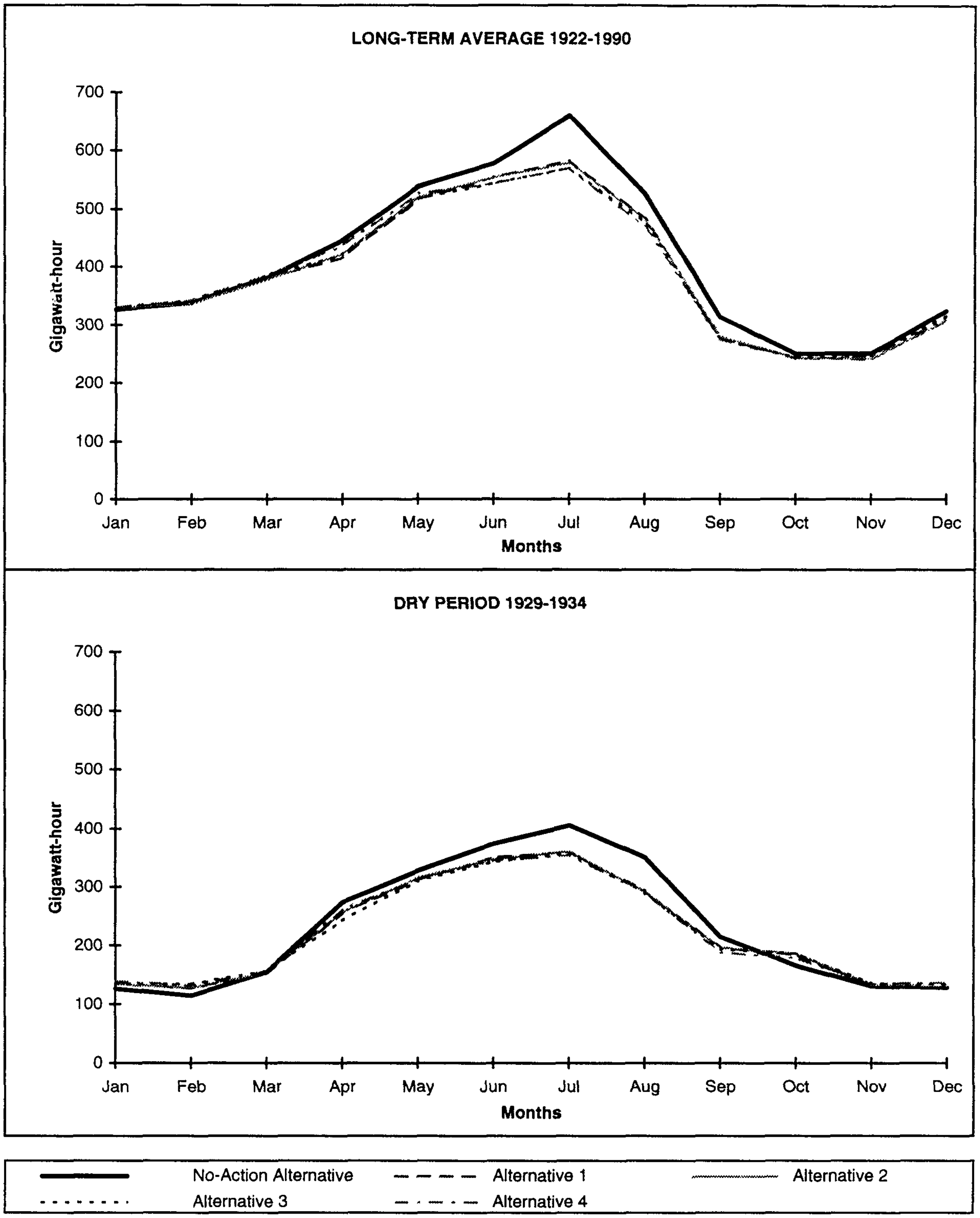


FIGURE III-2

SIMULATED AVERAGE MONTHLY CVP GENERATION

TABLE III-2

COMPARISON OF SIMULATED AVERAGE MONTHLY CVP GENERATION

LONG-TERM AVERAGE (1922-1990) (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	327	327	329	331	331
Feb	339	337	337	343	343
Mar	381	380	378	385	386
Apr	445	415	422	420	436
May	538	517	521	519	527
Jun	577	553	553	543	543
Jul	659	582	578	570	569
Aug	526	484	483	477	469
Sep	314	278	281	277	275
Oct	251	244	244	244	242
Nov	252	242	243	248	246
Dec	325	309	309	317	314
Average Annual Total	4,935	4,667	4,678	4,674	4,682
Percent Change		-5.4%	-5.2%	-5.3%	-5.1%
DRY YEAR PERIOD (1929-1934) (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	126	135	134	135	139
Feb	114	127	128	135	132
Mar	155	151	153	157	156
Apr	274	256	257	243	261
May	327	312	316	310	313
Jun	374	350	347	342	345
Jul	405	359	360	357	354
Aug	350	293	292	289	290
Sep	214	196	196	193	188
Oct	166	183	186	186	178
Nov	131	132	133	135	134
Dec	129	132	132	135	137
Average Annual Total	2,764	2,626	2,633	2,618	2,630
Percent Change		-5.0%	-4.7%	-5.3%	-4.9%

Notes:
Facilities include Trinity, Carr, Spring Creek, Shasta, Keswick, Folsom, Nimbus, New Melones, and San Luis with losses.

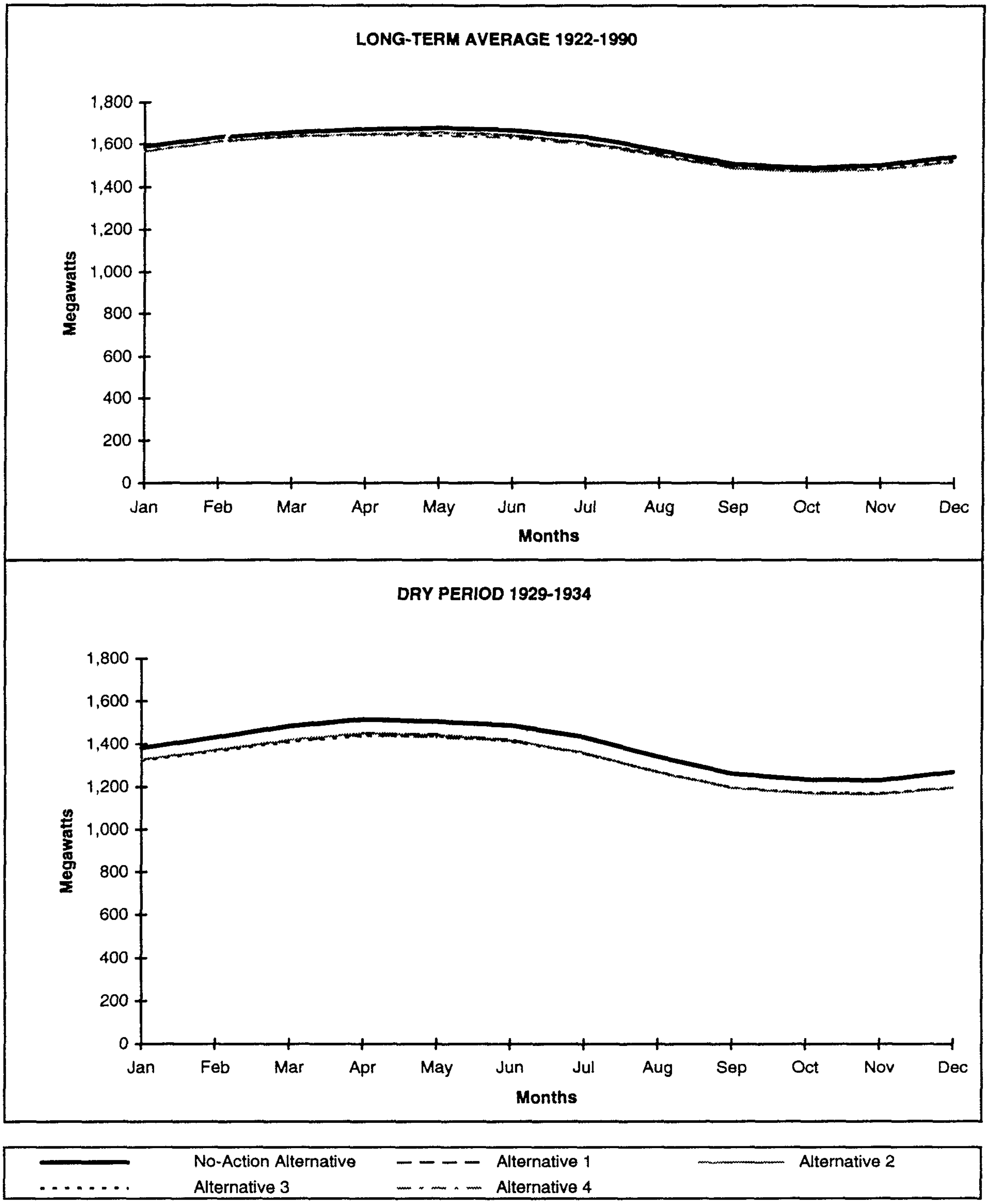


FIGURE III-3

SIMULATED AVERAGE MONTHLY AVAILABLE CAPACITY

TABLE III-3

COMPARISON OF SIMULATED AVERAGE MONTHLY AVAILABLE CAPACITY

LONG-TERM AVERAGE (1922-1990) (MW)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	1,589	1,566	1,566	1,567	1,565
Feb	1,633	1,612	1,612	1,612	1,611
Mar	1,660	1,640	1,640	1,638	1,640
Apr	1,675	1,653	1,653	1,649	1.646
May	1,680	1,659	1,658	1,656	1,643
Jun	1,671	1,647	1,645	1,645	1,633
Jul	1,637	1,609	1,607	1,608	1,599
Aug	1,572	1,551	1,550	1,554	1,546
Sep	1,507	1,488	1,488	1,491	1,487
Oct	1,491	1,474	1,474	1,479	1,474
Nov	1,503	1,482	1,482	1,488	1,482
Dec	1,543	1,521	1,521	1,524	1,520
Average Annual Total	19,161	18,901	18,896	18,911	18,846
Average Monthly	1,597	1,575	1,575	1,576	1,571
Percent Change		-1.4%	-1.4%	-1.3%	-1.6%
DRY YEAR PERIOD (1929-1934) (MW)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	1,382	1,326	1,326	1,323	1,327
Feb	1,432	1,372	1,372	1,366	1,370
Mar	1,485	1,420	1,420	1,410	1,415
Apr	1,515	1,451	1,451	1,439	1,443
May	1,504	1,444	1,442	1,437	1,432
Jun	1,487	1,420	1,417	1,414	1,415
Jul	1,432	1,356	1,358	1,353	1,354
Aug	1,339	1,267	1,265	1,267	1,267
Sep	1,260	1,194	1,194	1,196	1,197
Oct	1,231	1,168	1,168	1,173	1,172
Nov	1,228	1,164	1,164	1,168	1,166
Dec	1,267	1,197	1,195	1,197	1,200
Average Annual Total	16,561	15,780	15,770	15,741	15,758
Average Monthly	1,380	1,315	1,314	1,312	1,313
Percent Change		-4.7%	-4.8%	-4.9%	-4.8%

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average and dry hydrologic conditions is 1,597 MWs and 1,380 MWs, respectively. Figures III-4 and III-5 (Tables III-4 and III-5) show the comparison of on- and off-peak Project Use capacity for the average and dry periods. The comparison of simulated CVP average monthly Project Use energy is presented in Figure III-6 and Table III-6. Simulated on- and off-peak Project Use energy for the average and dry periods are shown in Figures III-7 and III-8 (Tables III-7 and III-8). The average annual Project Use energy requirement for the No-Action Alternative was 1,425 GWh for the long term (1922-1990) and 974 GWh for the dry period (1929-1934).

For evaluation of the market value of power, the long-term average energy available from PROSIM was used. The capacity values were based on the synthetic dry year discussed previously. Assumed generation and Project Use needs assumed for the synthetic year for each alternative are shown in Tables III-9, III-10, and III-11, respectively. The annual energy available and capacity available for sale (based on the synthetic year) are shown in Table III-12. Table III-13 shows the change in market value of power as compared to the No-Action Alternative. The average annual energy available for sale under the No-Action Alternative is 3,511 GWh. Based on the 90 percent exceedence synthetic dry year, the capacity for sale with energy for the No-Action Alternative was 756 MWs and the capacity for sale without energy was 708 Mws. The estimated average annual market value of CVP power for the No-Action Alternative is $125,800,000 (Western, 1997).

ALTERNATIVE 1

Water management provisions in Alternative 1 were developed to utilize two of the tools provided by CVPIA, Re-operation and (b)(2) Water Management, toward meeting the target flows for chinook salmon and steelhead trout in the Central Valley streams. For the purposes of Alternative 1, it was assumed that no water would be acquired from willing sellers. In addition, Alternative 1 assumed the implementation of several concurrent programs recognized or authorized under CVPIA. These programs included implementation of the Trinity River Mainstream Fisheries Restoration which may increase instream Trinity River flow requirements, provisions for a firm Level 2 water supply (historical average supply) for the refuges in accordance with the Refuge Water Supply Study and San Joaquin Basin Action Plan, and retirement of lands in accordance with the San Joaquin Valley Drainage Study. The water management actions under Alternative 1 primarily affect CVP-controlled streams.

The CVP is operated under Alternative 1 to attempt to increase end-of-month storage in September in Shasta and Folsom lakes in order to provide increased river releases in the fall into the Sacramento and American rivers as compared to the No-Action Alternative. Increased reservoir releases are also made from Whiskeytown Lake to increase Clear Creek minimum flows year round, and from New Melones Reservoir to provide higher flows on the Stanislaus River to meet flow targets in April through June. Increased Clair Engle Lake releases to meet increased Trinity River flow requirements in this alternative, result in a decrease in spring and summer diversions to the Sacramento River.

Average annual CVP power generation under this alternative is reduced at Trinity, Carr, and Spring Creek powerplants, as compared to the No-Action Alternative, due to increases in minimum instream flows in the Trinity River. Power generation is also slightly reduced at New

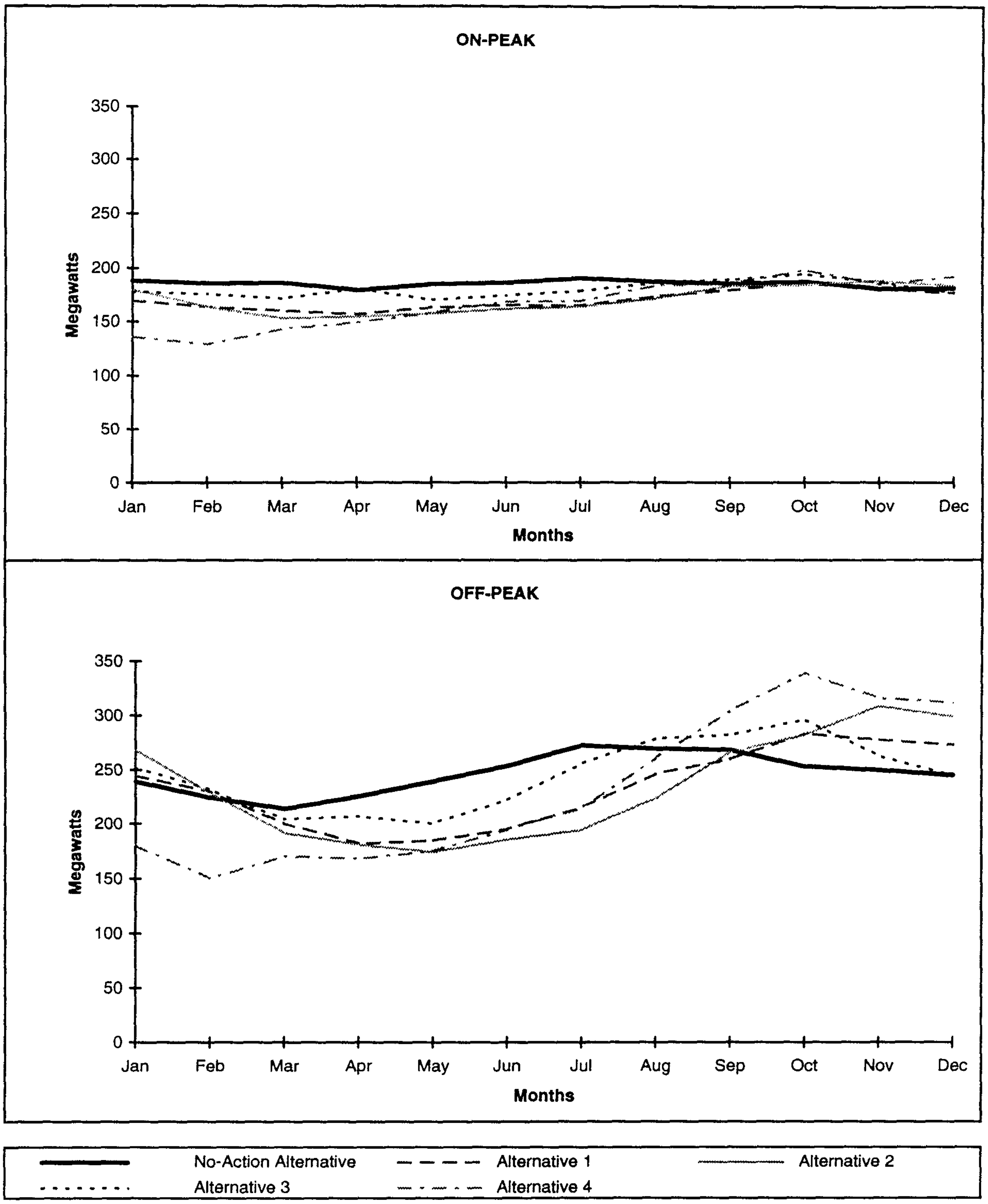

FIGURE III-4
SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE CAPACITY LONG-TERM AVERAGE 1922-1990

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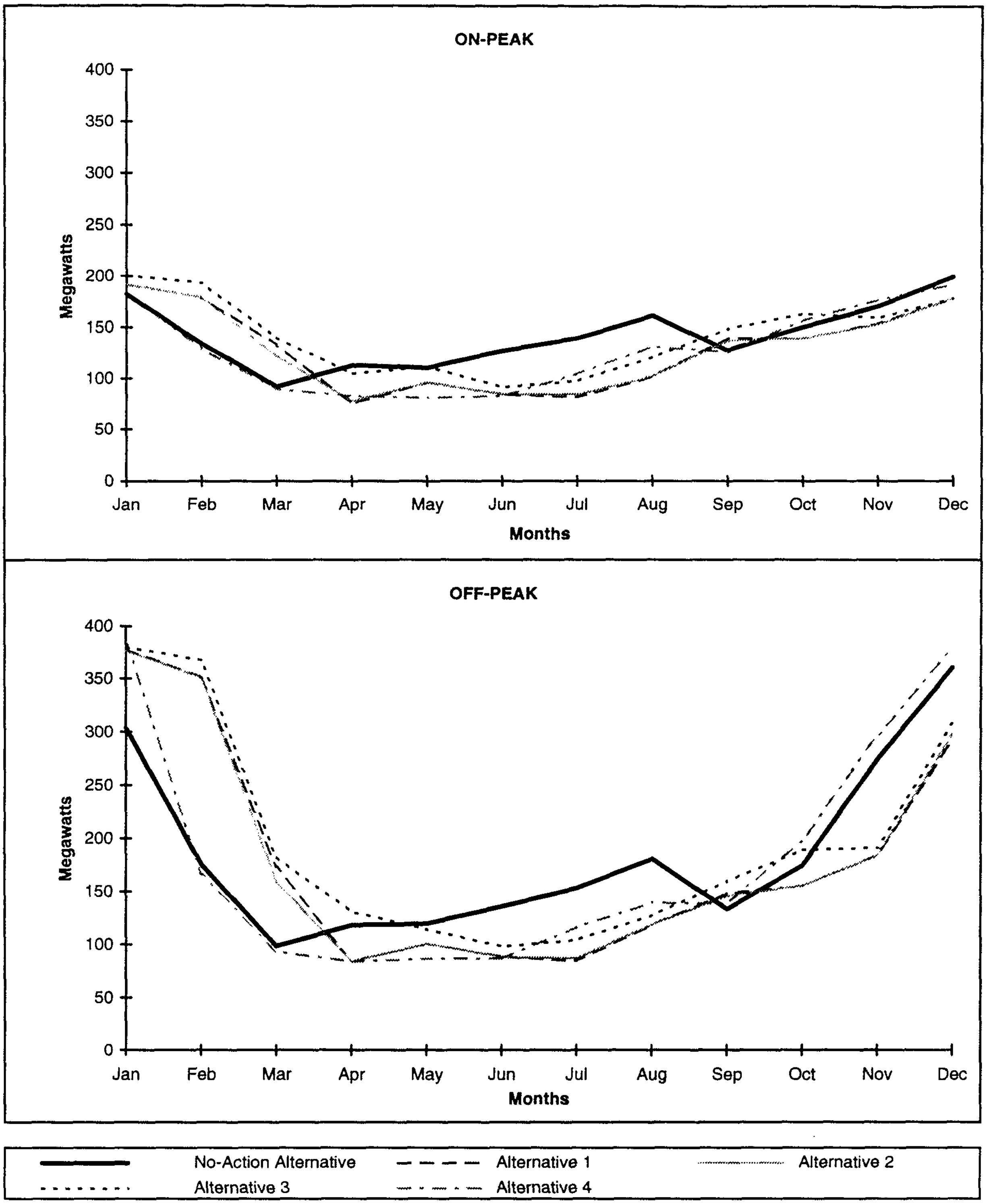

FIGURE III-5
SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE CAPACITY DRY YEAR PERIOD 1929-1934

TABLE III-4

COMPARISON OF SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE CAPACITY LONG-TERM AVERAGE 1922-1990

ON-PEAK (MW)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	188	169	179	177	136
Feb	185	163	163	175	129
Mar	186	160	153	171	143
Apr	178	157	155	180	149
May	184	163	158	169	158
Jun	186	165	162	174	168
Jul	190	164	164	178	168
Aug	187	173	171	185	183
Sep	185	179	183	188	184
Oct	186	185	183	194	197
Nov	180	180	187	185	184
Dec	180	176	182	176	191
Average Annual	2,213	2,033	2,039	2,152	1,991
Average Monthly	184	169	170	179	166
Percent Change		-8.1%	-7.9%	-2.8%	-10.0%
OFF-PEAK (MW)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	239	245	268	252	181
Feb	225	230	229	232	150
Mar	214	200	191	204	171
Apr	226	182	181	207	168
May	239	185	174	200	175
Jun	254	195	186	222	194
Jul	272	215	194	256	214
Aug	269	246	224	279	261
Sep	268	260	266	282	304
Oct	253	283	282	296	339
Nov	250	278	308	263	316
Dec	245	273	299	244	312
Average Annual Total	2,954	2,791	2,803	2,937	2,785
Average Monthly	246	233	234	245	232
Percent Change		-5.5%	-5.1%	-0.6%	-5.7%

TABLE III-5

COMPARISON OF SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE CAPACITY DRY YEAR PERIOD 1929-1934

ON-PEAK (MW)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	182	192	192	201	184
Feb	134	179	179	193	129
Mar	92	132	121	139	90
Apr	113	76	79	104	83
May	110	96	96	111	81
Jun	126	85	85	92	83
Jul	139	82	85	97	104
Aug	161	102	102	120	131
Sep	127	139	136	148	126
Oct	150	139	139	163	157
Nov	170	154	153	159	176
Dec	199	178	178	178	191
Average Annual Total	1,703	1,551	1,544	1,706	1,534
Average Monthly	142	129	129	142	128
Percent Change		-8.9%	-9.3%	0.2%	-9.9%
OFF-PEAK (MW)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	304	378	376	380	386
Feb	175	351	351	367	166
Mar	98	173	159	182	93
Apr	118	84	84	131	84
May	119	100	101	114	87
Jun	136	89	89	98	87
Jul	153	84	87	104	116
Aug	180	118	118	127	139
Sep	133	148	145	159	138
Oct	174	155	155	189	198
Nov	274	184	183	191	296
Dec	360	291	298	307	379
Average Annual Total	2,224	2,154	2,146	2,349	2,168
Average Monthly	185	180	179	196	181
Percent Change		-3.1%	-3.5%	5.6%	-2.5%

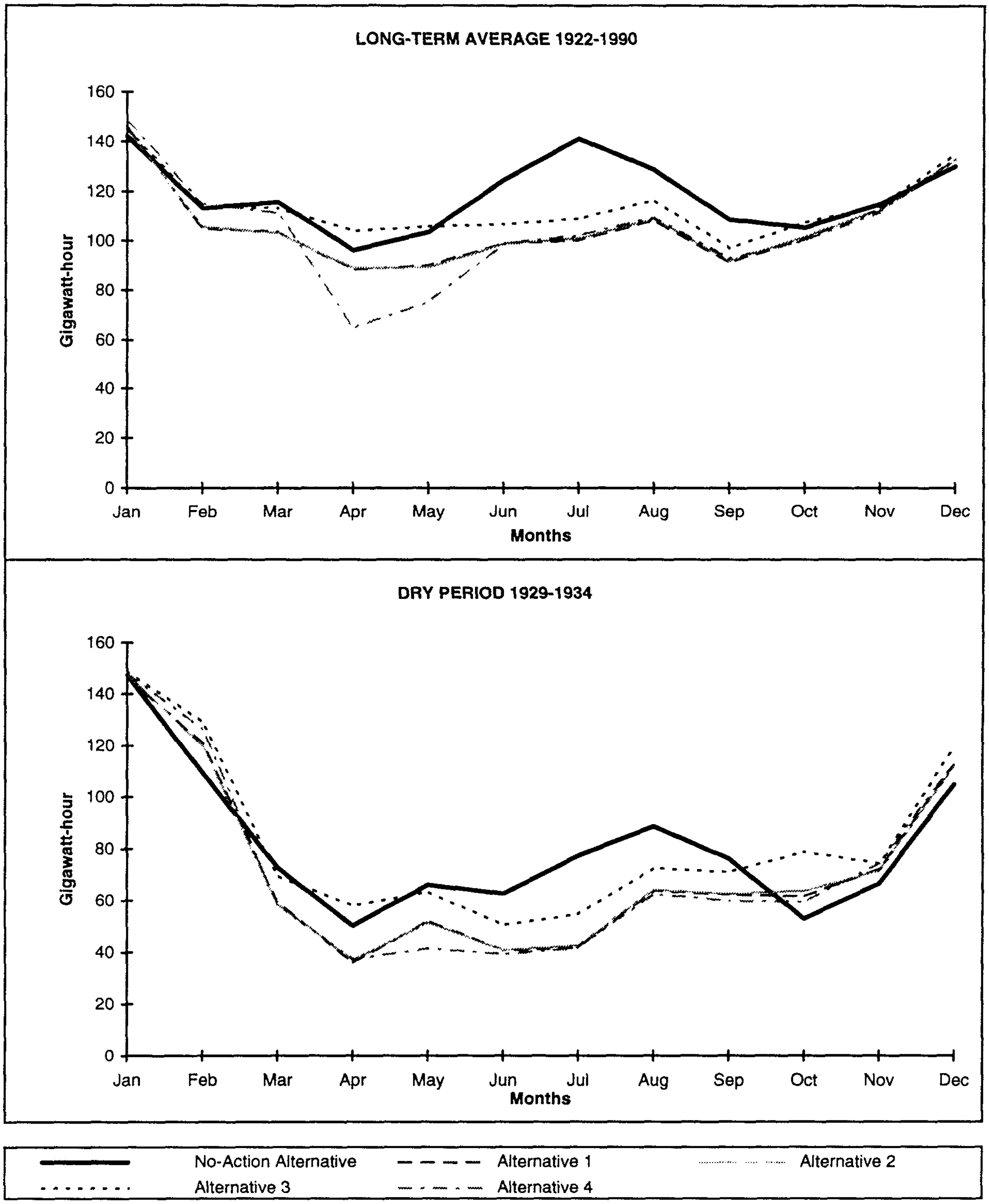

FIGURE III-6

SIMULATED AVERAGE MONTHLY CVP PROJECT USE ENERGY

TABLE III-6

COMPARISON OF SIMULATED AVERAGE MONTHLY CVP PROJECT USE

LONG-TERM AVERAGE (1922-1990) (GWh)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	142	146	145	145	148
Feb	113	105	106	114	115
Mar	116	104	103	113	111
Apr	96	88	89	104	65
May	104	90	89	106	75
Jun	125	99	99	107	99
Jul	141	100	101	109	102
Aug	129	108	109	116	109
Sep	109	91	92	97	93
Oct	105	101	102	107	100
Nov	115	113	113	114	112
Dec	130	133	133	136	134
Average Annual Total	1,425	1,278	1,280	1,367	1,263
Percent Change		-10.3%	-10.2%	-4.0%	-11.3%
DRY YEAR PERIOD (1929-1934) (GWh)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	147	147	147	149	148
Feb	109	121	120	129	126
Mar	73	60	58	70	59
Apr	50	36	37	58	37
May	66	52	51	63	42
Jun	63	41	41	50	39
Jul	77	42	43	55	42
Aug	89	64	64	73	63
Sep	76	62	63	71	60
Oct	53	62	64	79	59
Nov	67	72	72	74	75
Dec	105	112	112	119	113
Average Annual Total	974	870	871	990	862
Percent Change		-10.7%	-10.6%	1.5%	-11.5%

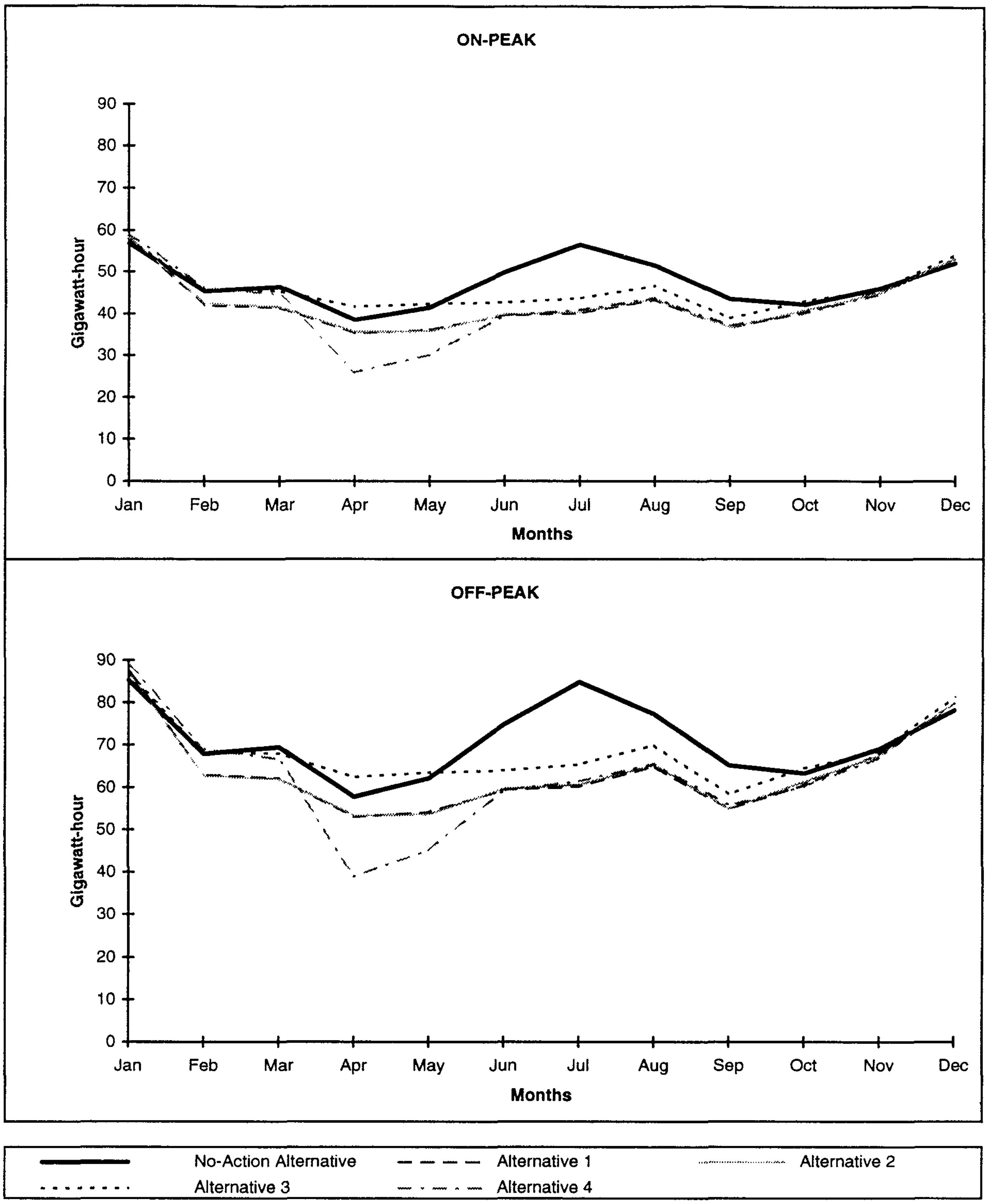

FIGURE III-7
SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE ENERGY LONG-TERM AVERAGE 1922-1990

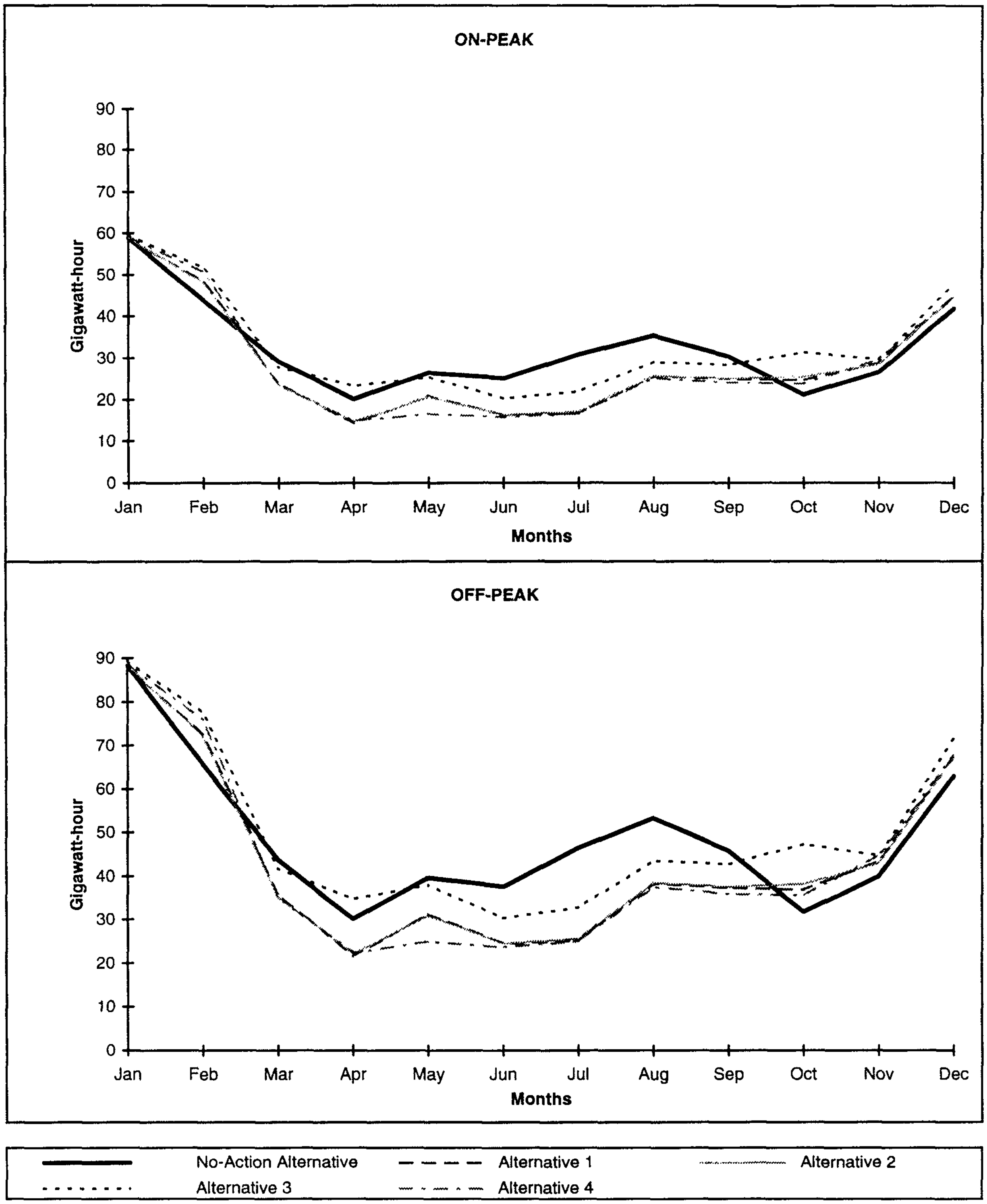

FIGURE III-8
SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE ENERGY DRY YEAR PERIOD 1929-1934

TABLE III-7

COMPARISON OF SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE ENERGY LONG-TERM AVERAGE 1922-1990

ON-PEAK (GWh)	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	57	58	58	58	59
Feb	45	42	42	45	46
Mar	46	41	42	45	44
Apr	38	35	36	42	26
May	41	36	36	42	30
Jun	50	40	40	43	40
Jul	56	40	40	44	41
Aug	51	43	43	47	44
Sep	43	37	37	39	37
Oct	42	40	41	43	40
Nov	46	45	45	46	45
Dec	52	53	53	54	53
Average Annual Total	570	511	513	547	505
Percent Change		-10.3%	-10.0%	-4.0%	-11.3%

OFF-PEAK (GWh)	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	85	87	87	87	89
Feb	68	63	63	68	69
Mar	69	62	62	68	67
Apr	58	53	53	62	39
May	62	54	54	63	45
Jun	75	59	60	64	59
Jul	85	60	61	65	61
Aug	77	65	65	70	66
Sep	65	55	55	58	56
Oct	63	60	61	64	60
Nov	69	68	67	69	67
Dec	78	80	80	81	80
Average Annual Total	855	767	768	820	758
Percent Change		-10.3%	-10.2%	-4.0%	-11.3%

TABLE III-8

COMPARISON OF SIMULATED AVERAGE MONTHLY ON- AND OFF-PEAK CVP PROJECT USE ENERGY DRY YEAR PERIOD 1929-1934

ON-PEAK (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	59	59	59	60	59
Feb	44	48	48	52	51
Mar	29	24	23	28	23
Apr	20	14	15	23	15
May	26	21	21	25	17
Jun	25	16	16	20	16
Jul	31	17	17	22	17
Aug	35	26	26	29	25
Sep	30	25	25	28	24
Oct	21	25	25	32	24
Nov	27	29	29	30	30
Dec	42	45	45	48	45
Average Annual Total	390	348	349	396	345
Percent Change		-10.7%	-10.6%	1.5%	-11.5%
OFF-PEAK (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	88	88	88	89	89
Feb	66	73	72	78	76
Mar	44	36	35	42	35
Apr	30	22	22	35	22
May	40	31	31	38	25
Jun	38	24	24	30	24
Jul	46	25	26	33	25
Aug	53	38	38	44	38
Sep	46	37	38	43	36
Oct	32	37	38	47	36
Nov	40	43	43	45	45
Dec	63	67	67	71	68
Average Annual Total	585	522	523	594	517
Percent Change		-10.7%	-10.6%	1.5%	-11.6%

TABLE III-9

90 PERCENT EXCEEDENCE SYNTHETIC DRY YEAR MONTHLY CVP GENERATION

PROSIM CAPACITY (MW)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	1,509	1415	1518	1,492	1,252
Feb	1,534	1382	1387	1,462	1,375
Mar	1,445	1500	1502	1,503	1,497
Apr	1,491	1498	1456	1,486	1,351
May	1,676	1566	1568	1,577	1,451
Jun	1,529	1447	1512	1,452	1,445
Jul	1,521	1468	1429	1,469	1,471
Aug	1,395	1333	1346	1,355	1,336
Sep	1,352	1429	1335	1,295	1,272
Oct	1,423	1335	1344	1,321	1,342
Nov	1,325	1278	1284	1,123	1,239
Dec	1,366	1427	1428	1,153	1,422
Total	17,566	17,078	17,110	16,688	16,452
Average Monthly	1,464	1,423	1,426	1,391	1,371
Percent Change		-2.8%	-2.6%	-5.0%	-6.3%
TOTAL ENERGY (GWh)					
	No-Action Alternative	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Jan	123	137	135	137	141
Feb	114	130	131	133	139
Mar	168	167	168	171	180
Apr	272	255	259	253	260
May	347	353	352	354	319
Jun	398	375	371	359	361
Jul	446	398	401	390	391
Aug	357	332	331	328	328
Sep	228	215	206	202	200
Oct	154	168	169	171	171
Nov	139	140	141	148	143
Dec	133	135	139	143	143
Total	2,878	2,808	2,804	2,788	2,777
Percent Change		-2.4%	-2.6%	-3.1%	-3.5%

Source:
Western, 1997.

TABLE III-10

90 PERCENT EXCEEDENCE SYNTHETIC DRY YEAR ON- AND OFF-PEAK CVP PROJECT USE CAPACITY

MAXIMUM ON-PEAK (MW)	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	204	187	199	191	200
Feb	199	154	154	97	156
Mar	112	48	48	49	116
Apr	128	73	112	74	63
May	158	119	119	148	124
Jun	150	56	79	57	57
Jul	135	69	110	71	75
Aug	149	105	106	106	145
Sep	159	172	91	153	155
Oct	151	146	146	169	146
Nov	154	151	151	151	151
Dec	141	190	190	196	192
Total	1,840	1,470	1,505	1,462	1,580
Average Monthly	153	123	125	122	132
Percent Change		-20.1%	-18.2%	-20.5%	-14.1%

OFF-PEAK (MW)	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	317	387	434	334	440
Feb	296	299	299	97	300
Mar	156	48	48	50	116
Apr	147	73	126	90	71
May	175	127	126	159	122
Jun	176	67	79	70	69
Jul	148	71	122	71	82
Aug	185	113	133	123	172
Sep	165	216	93	153	155
Oct	151	146	146	169	146
Nov	198	195	195	179	180
Dec	191	356	358	365	365
Total	2,305	2,098	2,159	1,860	2,218
Average Monthly	192	175	180	155	185
Percent Change		-9.0%	-6.3%	-19.3%	-3.8%

Source:
Western, 1997.

TABLE III-11

90 PERCENT EXCEEDENCE SYNTHETIC DRY YEAR ON- AND OFF-PEAK CVP PROJECT USE ENERGY

ON-PEAK (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	59	58	61	57	60
Feb	50	40	39	8	40
Mar	25	6	6	8	11
Apr	31	11	28	16	10
May	40	29	29	37	28
Jun	37	14	14	15	15
Jul	35	11	29	11	15
Aug	40	25	25	27	38
Sep	29	37	18	22	22
Oct	27	25	25	31	25
Nov	33	28	28	27	25
Dec	26	54	55	55	54
Total	432	336	356	313	343
Percent Change		-22.2%	-17.6%	-27.5%	-20.6%
OFF-PEAK (GWh)					
	No-Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Jan	89	87	91	86	90
Feb	75	60	59	12	60
Mar	38	9	9	12	17
Apr	47	17	41	23	15
May	59	43	43	56	42
Jun	56	22	21	22	22
Jul	52	16	43	16	22
Aug	60	37	38	40	57
Sep	44	55	27	33	33
Oct	41	37	38	46	38
Nov	50	41	41	41	38
Dec	40	82	81	82	81
Total	650	506	534	469	515
Percent Change		-22.2%	-17.8%	-27.8%	-20.8%

Source:
Western, 1997.

TABLE III-12

CVP ENERGY AND CAPACITY AVAILABLE FOR SALE

Alternative	Average Annual Energy (GWh)	90 Percent Exceedence Average Monthly Synthetic Dry Year Capacity (MW)	
		With Energy	Without Energy
No-Action	3,511	756	708
1	3,391	801	622
2	3,401	777	649
3	3,308	780	611
4	3,420	776	595

TABLE III-13

ANNUAL CHANGE IN MARKET VALUE OF CVP POWER COMPARED TO THE NO-ACTION ALTERNATIVE (Million $)

Alternative	Average Annual Energy	90 Percent Exceedence Synthetic Dry Year Capacity		Total
		With Energy	Without Energy	
1	-2.0	3.4	-1.3	0.1
2	-1.9	1.6	-0.9	-1.1
3	-3.2	1.8	-1.5	-2.8
4	-1.6	1.5	-1.7	-1.8

Melones powerplant due to changes in reservoir operations under (b)(2) Water Management. Comparisons of the simulated average annual generation for each powerplant, between Alternative 1 and No-Action Alternative, are presented in Figure III-1. The reduction in average annual CVP generation under average and dry hydrologic conditions, for Alternative 1 as compared to the No-Action Alternative, is 5.4 percent and 5.0 percent respectively. The reduction in simulated average monthly total CVP available capacity for the average and dry periods is 1.4 percent and 4.7 percent respectively. The changes in average monthly generation and available capacity are primarily due to the decreased diversions from the Trinity River Basin in the spring and summer, and increased CVP reservoir releases in the fall and spring months under the (b)(2) Water Management. Monthly generation and available capacity are shown in Figures III-2 and III-3.

Changes in CVP pumping plant operations result in differences in the average monthly CVP Project Use energy and capacity in Alternative 1, as compared to the No-Action Alternative. Increased fall and reduced summer Tracy Pumping Plant exports, and increased fall pumping to lift water into San Luis Reservoir shift the simulated average monthly Project Use capacity. Project Use needs are reduced during the spring and summer and are increased in the fall and winter months. These shifts in Project Use energy and capacity requirements are shown in Figures III-4 through III-8. Overall, the average annual Project Use energy is reduced 10.3 percent compared to the No-Action Alternative.

The market value of power was determined using the long term average energy available from PROSIM and capacity values based on the synthetic dry year discussed previously. Generation and Project Use needs assumed for the synthetic year are shown in Tables III-9, III-10, and III-11. The energy available for sale under average conditions decreases by 3.4 percent compared to the No-Action Alternative, resulting in a reduction in energy value. However, the energy available for sale under adverse conditions is greater than in the No-Action Alternative, resulting in higher firm load carrying capability value (capacity with energy). This increase in capacity with energy for sale of 6.0 percent under adverse conditions offsets the reduction in value due to reduced average year energy. Energy and Capacity available for sale are shown in Table III-12. Capacity without energy for sale decreased by 12.1 percent. Based on the market value of power analysis, the net increase in the value of CVP power production under Alternative 1, as compared to the No-Action Alternative, is approximately $100,000 per year. The relative change in values of energy and capacity are shown in Table III-13. A detailed discussion of the results of the value of power analysis is presented in the PEIS Impacts Study conducted by Western (Western, 1997).

ALTERNATIVE 2

Alternative 2 includes the CVPIA provisions in Alternative 1, plus the acquisition of surface water from willing sellers toward meeting the delivery of Level 4 water supplies to refuges and meeting the target flows for chinook salmon and steelhead trout in the Central Valley streams. The Re-operation and (b)(2) Water Management components of Alternative 2 are similar to these components in Alternative 1. Also similar to Alternative 1, Alternative 2 includes implementation of the habitat restoration actions.

In Alternative 2, water would be acquired to provide delivery of Level 4 water supply requirements to wildlife refuges. Level 4 water supplies represent the water needs for the long-term development of the refuges as described in the Refuge Water Supply Study and the San Joaquin Basin Action Plan. It is assumed that this water would be acquired from reliable sources within the same geographic region as the refuges.

In addition, Alternative 2 includes the acquisition of water on the Stanislaus, Tuolumne, and Merced rivers to attempt to meet salmon and steelhead target flows on these streams, primarily in the April through June period, and to provide increased Delta outflow. Because this water would be acquired for both instream flows and Delta outflow, it could not be pumped by export facilities in the Delta.

These water acquisitions would be limited by the remaining funds assumed to be available in the CVPIA Restoration Fund after the Restoration Actions and acquisition of Level 4 water supplies for refuges are implemented. The release of acquired water to increase flows on the Stanislaus, Tuolumne, and Merced rivers would result in increased flows in the San Joaquin River at Vernalis during April and May, coinciding with the timing of Bay-Delta Plan Accord pulse flow requirements.

Average annual CVP generation under Alternative 2 is reduced at Trinity, Carr, and Spring Creek powerplants, as compared to the No-Action Alternative, due to increases in minimum instream flows in the Trinity River. Generation is also reduced at New Melones powerplant due to changes in reservoir operations under (b)(2) Water Management, similar to Alternative 1, and due to acquired water releases in the spring for Stanislaus River flow targets. Comparisons of the simulated average annual generation for each powerplant, between Alternative 2 and No-Action Alternative, are presented in Figure III-1. The reduction in average annual CVP generation under average and dry hydrologic conditions, for Alternative 2 as compared to the No-Action is 5.2 percent and 4.7 percent respectively. The reduction in simulated average monthly total CVP available capacity for average and dry periods is 1.4 percent and 4.8 percent respectively. Monthly generation and available capacity are shown in Figures III-2 and III-3.

Alternative 2 CVP pumping plant operations are similar to Alternative 1. Increased fall and reduced summer Tracy Pumping Plant exports, and increased fall pumping to lift water into San Luis Reservoir shift the simulated average monthly Project Use capacity. The distribution of average monthly CVP Project Use energy also shifts in Alternative 2, as in Alternative 1, due primarily to increased fall and reduced summer Tracy Pumping Plant exports. These shifts in Project Use capacity and energy requirements are shown in Figures III-4 through III-8. Overall, the average annual Project Use energy is reduced 10.2 percent compared to the No-Action Alternative.

The market value of power was determined using the long term average energy available from PROSIM and capacity values based on the synthetic dry year discussed previously. Generation and Project Use needs assumed for the synthetic year are shown in Tables III-9, III-10, and III-11. The energy available for sale under average conditions decreases by 3.2 percent compared to the No-Action Alternative, resulting in a reduction in energy value. However, the energy available for sale under adverse conditions is greater than in the No-Action Alternative, resulting in higher firm load carrying capability value. This increase in capacity with energy for sale of 2.8 percent under adverse conditions partially offsets the reduction in value due to reduced average year energy. Capacity without energy for sale decreased by 8.4 percent. Energy and Capacity available for sale are shown in Table III-12. Based on the market value of power analysis, the net decrease in the value of CVP power production under Alternative 2, as compared to the No-Action Alternative, is approximately $1,100,000 per year. The relative change in values of energy and capacity are shown in Table III-13.

ALTERNATIVE 3

Water management provisions in Alternative 3 include the provisions in Alternative 2, as well the acquisition of surface water from willing sellers toward meeting Level 4 water supplies for refuges, and acquisition towards chinook salmon and steelhead flow needs in the Central Valley streams. These Central Valley streams include the Tuolumne, Merced, Stanislaus, Calaveras, Mokelumne, and Yuba Rivers. Water acquired for instream purposes may be exported by the CVP and SWP when it flows into the Delta.

The Re-operation and (b)(2) Water Management components of Alternative 3 would be similar to these components in Alternative 1.

Average annual CVP generation under Alternative 3 is reduced at Trinity, Carr, and Spring Creek powerplants, as compared to the No-Action Alternative, due to increases in minimum instream flows in the Trinity River. Generation is also reduced at New Melones powerplant due to changes in reservoir operations under (b)(2) Water Management, similar to Alternative 1, and due to acquired water releases in the spring for Stanislaus River flow targets. Comparisons of the simulated average annual generation for each powerplant, between Alternative 3 and No-Action Alternative, are presented in Figure III-1. The reduction in average annual CVP generation under average and dry hydrologic conditions, for Alternative 3 as compared to the No-Action is 5.3 percent for both average and dry conditions. The reduction in simulated average monthly total CVP available capacity for average and dry periods is 1.3 percent and 5.0 percent respectively. Monthly generation and available capacity are shown in Figures III-2 and III-3.

In Alternative 3, acquired water can be exported after it flows into the Delta as long as requirements of the Bay-Delta Accord are met. This results in increased Tracy Pumping Plant exports as compared to Alternatives 1 and 2. A comparison of average monthly on- and off-peak CVP Project Use capacity for average and dry periods, as compared to the No-Action Alternative, is presented in Figures III-4 and III-5. The average monthly CVP Project Use energy requirements also increase in the fall and decrease in the summer in Alternative 3, as compared to the No-Action Alternative, as shown in Figure III-6. Simulated on- and off-peak Project Use energy for the average and dry periods are shown in Figures III-7 and III-8. Overall, the average annual Project Use energy is reduced 4.0 percent compared to the No-Action Alternative.

The market value of power was determined using the long term average energy available from PROSIM and capacity values based on the synthetic dry year discussed previously. Generation and Project Use needs assumed for the synthetic year are shown in Tables III-9, III-10, and III-11. The energy available for sale under average conditions decreases by 5.8 percent compared to the

No-Action Alternative, resulting in a reduction in energy value. However, the energy available for sale under adverse conditions is greater than in the No-Action Alternative, resulting in higher firm load carrying capability value. This increase in capacity with energy for sale of 3.2 percent under adverse conditions partially offsets the reduction in value due to reduced average year energy. Capacity without energy for sale decreased by 13.7 percent. Energy and Capacity available for sale are shown in Table III-12. Based on the market value of power analysis, the net decrease in the value of CVP power production under Alternative 3, as compared to the No-Action Alternative, is approximately $2,800,000 per year. The relative change in values of energy and capacity are shown in Table III-13.

ALTERNATIVE 4

Alternatives 1 through 3 include the evaluation of the use of (b)(2) water to meet target flows on CVP controlled streams and towards 1995 Water Quality Control Plant requirements, firm Level 2 refuge supplies, and revised minimum streamflow requirements on the Trinity River. In addition, Alternative 4 includes the use of (b)(2) water to attempt to meet fisheries objectives in the Delta. Similar to Alternative 1, a simplified version of the (b)(2) Water Management was developed that integrated Delta (b)(2) water actions into Alternative 4.

Similar to Alternative 3, Alternative 4 includes acquisition of surface water from willing sellers toward meeting Level 4 water supplies for refuges, and acquisition towards chinook salmon and steelhead flow needs in the Central Valley streams. These Central Valley streams include the Tuolumne, Merced, Stanislaus, Calaveras, Mokelumne, and Yuba Rivers. In Alternative 4 water is acquired for instream and Delta outflow purposes, and would not be exported by the CVP or SWP.

Average annual CVP power generation under Alternative 4 is reduced at Trinity, Carr, and Spring Creek powerplants, as compared to the No-Action Alternative, due to increases in minimum instream flows in the Trinity River. Power generation is also reduced at Melones powerplant due to changes in reservoir operations under (b)(2) Water Management, similar to Alternative 1, and due to acquired water releases in the spring for Stanislaus River flow targets. Comparisons of the simulated average annual generation for each powerplant, between Alternative 4 and the No-Action Alternative, are presented in Figure III-1. The reduction in average annual CVP generation under average and dry hydrologic conditions, for Alternative 4 as compared to the No-Action Alternative, is 5.1 percent and 4.9 percent respectively. The reduction in simulated average monthly total CVP available capacity is similar to Alternatives 1 through 3, for the average and dry periods is 1.6 percent ad 4.9 percent. Monthly generation and available capacity are shown in Figures III-2 and III-3.

In Alternative 4 the CVP would not export acquired water after it flows into the Delta, and Tracy Pumping Plant exports would be limited April 15 through May 15. This results in decreased Tracy Pumping Plant energy needs as compared to the other Alternatives. A comparison of average monthly on- and off-peak CVP Project Use capacity for average and dry periods, as compared to the No-Action Alternative, is presented in Figures III-4 and III-5. The Alternative 4 average monthly CVP Project Use energy requirements, presented in Figure III-6, show the reduction in Project Use energy in April and May, as compared to the No-Action Alternative.

Simulated on- and off-peak Project Use energy, for the average and dry periods, is shown in Figures III-7 and III-8. Overall, the average annual Project Use energy is reduced 11.3 percent compared to the No-Action Alternative.

The market value of power was determined using the long term average energy available from PROSIM and capacity values based on the synthetic dry year discussed previously. Generation and Project Use needs assumed for the synthetic year are shown in Tables III-9, III-10, and III-11. The energy available for sale under average conditions decreases by 2.6 percent compared to the No-Action Alternative, resulting in a reduction in energy value. However, the energy available for sale under adverse conditions is greater than in the No-Action Alternative, resulting in higher firm load carrying capability value. This increase in capacity with energy for sale of 2.6 percent under adverse conditions partially offsets the reduction in value due to reduced average year energy. Capacity without energy for sale decreased by 15.9 percent. Energy and Capacity available for sale are shown in Table III-12. Based on the market value of power analysis, the net decrease in the value of CVP power production under Alternative 4, as compared to the No-Action Alternative, is approximately $1,800,000 per year. The relative change in values of energy and capacity are shown in Table III-13.

CHAPTER IV

BIBLIOGRAPHY

Chapter IV

BIBLIOGRAPHY

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